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Isometric Strength Position Specificity Resulting From Isometric and Isotonic Training as a Determinant in Performance.

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ISOMETRIC STRENGTH POSITION SPECIFICITY RESULTING FROM ISOMETRIC AND ISOTONIC TRAINING AS A DETERMINANT IN PERFORMANCE

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by
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DEDICATION

To my parents, Raymond and Jo Sterling,

and my wife, Patricia

ACKNOWLEDGMENT

For their assistance and continued encouragement in the preparation of this dissertation, the author wishes to express his sincere appreciation to the following individuals: Dr. Francis Drury, for his guidance throughout the pursuit of the degree as major professor; Dr. Jack Nelson, for his advice on statistics and design; and the students of Central Missouri State College who so willingly served as subjects in this project.

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ABSTRACT

It was the purpose of this study to compare the effects of isometric exercise at 95°, 125°, and 155° of knee extension; isotonic exercise from 90° through 180° of knee extension; and a control group participating only in a physical education activity class, on (1) isometric strength at 95°, 125°, and 155° of knee extension, (2) isotonic strength from 90° through 180° of knee extension, and (3) vertical jumping ability.

One hundred twenty male undergraduate students were randomly divided into five groups of twenty-four subjects each. All groups participated in a one week familiarity routine in which they experienced all testing and training methods. All subjects were then administered isometric strength tests at 95°, 125°, and 155° angles of knee extension; an isotonic strength test from 90° through 180° of knee extension; and a vertical jump test.

Groups I, II, and III then trained at 95°, 125°, and 155° angles of knee extension, respectively. The training routine consisted of a single ten-second isometric contraction performed each training day, three days a week. Group IV trained isotonically from 90° through 180° of knee extension three days a week for ten seconds each day with the 4-RM. Group V was the control group and participated only in the physical education activity classes. All subjects were enrolled in physical education activity classes in addition to the training program.

During the seventh training week all subjects repeated the familiarity routine and the following week all subjects were administered the final test in all five testing situations.

The t test was applied to determine the significance of the difference between initial and final test means for each group on each test. The analysis of covariance technique was applied to determine the comparative effectiveness of the training methods on the criterion traits. Significant F-ratios were found on the 95° and 125° isometric tests as well as the isotonic test, and the orthogonal comparison technique was applied to determine where the significant differences existed among the groups on the criterion traits.

Within the limitations of this study, the following conclusions were set forth:

1. Isometric training at a 95° angle of knee extension was superior to isometric training at either 125° or 155° in improving isometric strength at the 95° angle. At 125° and 155°, isometric strength was significantly improved by isometric exercise at all three training angles, but no significant difference existed among the three isometric training techniques.

   The above conclusion indicated that position specificity of strength gains was found only at the 95° angle. Therefore, isometric exercise should be performed at 95°

if strength is to be developed at that angle, but isometric exercises at 95°, 125°, or 155° are equally effective in bringing about strength gains at 125° or 155° of knee extension.

2. Isotonic training was superior to the three isometric training methods in developing isotonic knee extensor strength. All three isometric training techniques did significantly improve isotonic knee extensor strength.
3. There were no significant differences among the three isometric training techniques and the isotonic training technique in improving vertical jumping ability and all four methods produced significant gains in vertical jumping ability.

CHAPTER I

INTRODUCTION

Isometric contraction exercise has become an important facet of a majority of the physical fitness programs advocated today. As with many popular concepts, isometric exercise has its dissenters as well as proponents. The question as to exactly what benefits can be derived from isometric exercise has frequently been asked. The questioner expects the answer to be backed by scientifically derived facts, not empirical opinion. The answer, if based on sound research, will undoubtedly be inconclusive.

A great majority of the research has found that isometric exercise increased strength measured both isometrically and isotonically. The findings regarding the effects of isometrics on such factors as muscular endurance, cardiovascular endurance, explosive force, speed of movement, reaction time and movement skill are not as conclusive.

Many specific questions such as the following have direct bearing on the final evaluation of isometric exercise: Does isometric exercise bring about strength gains throughout the range of motion or is position specificity involved? If position specificity is involved, does it differ from muscle group to muscle group? What are the boundaries of the position specificity and do they differ between muscle groups? Is position specificity a factor to be

considered in selecting the proper angle(s) at which to exercise? May strength gained isometrically be effectively utilized in movement? Although a few studies have been completed concerning these questions, little agreement has been reached as to the answers.

The investigation herein set forth does not submit to answering all of the above questions nor does it present absolute conclusions regarding the expressed purpose herein stated. However, the investigation was undertaken with the idea that it might shed more light on a few of the controversial aspects of isometric exercise. It was hoped that the study would be of value to the physical education and physical rehabilitation fields in the following ways:

1. It should increase the knowledge as to the value of isometric exercise for improving performance in dynamic strength movements.
2. It should increase the knowledge as to whether or not isotonic exercise brings about a specificity of strength gains.
3. It should increase the knowledge as to whether or not isometric exercise brings about a specificity of strength gains.

I. STATEMENT OF THE PROBLEM

The purpose of this study was to investigate the effects of isolated isometric and isotonic exercises on selected measures of

isometric and isotonic strength in the same range of motion and on dynamic explosive movement involving the same range of motion.

The specific problems of the study were:

1. To compare the effects of an isometric hip press exercise at one specific angle of knee extension on isometric hip press strength scores at a specific angle of the leg on the thigh (95°, 125°, 155°) and an isotonic strength score (1-RM) in the same range of motion.
2. To compare the effects of an isotonic hip press exercise through a specific range of motion on isometric hip press strength scores at a specific angle of the leg on the thigh (95°, 125°, 155°) and an isotonic strength score (1-RM) in the same range of motion.
3. To compare the effects of an isometric hip press exercise at one specific angle of knee extension (95°, 125°, 155°) and an isotonic hip press exercise through a specific range of motion on vertical jumping ability.

II. DELIMITATION OF THE STUDY

The subjects were male students enrolled in the required physical education activity program at Central Missouri State College, Warrensburg, Missouri during the ten week summer term of 1966. All varsity athletes and students who were participating in an extra class conditioning program were excluded from the study. Any

student in a restricted activity program due to a physical impairment was excluded from the study.

III. LIMITATIONS OF THE STUDY

All subjects were asked to refrain from vigorous physical activity other than that required in the physical education classes. There was no way of enforcing this request.

IV. DEFINITION OF TERMS

Angle of the leg on the thigh. The angle formed at the knee joint when one arm of a goniometer was placed along the frontal midline of the thigh and the other goniometer arm was placed in a frontal plane on a line between the lateral malleolus and the lateral condyle of the tibia.

Familiarity program. A one week program prior to the actual testing situation during which the subjects participated in numerous testing and training experiences.

Hip press. An exercise (either isometric or isotonic) in which the subject assumed a standing position with the knees flexed and the back parallel to the floor. The subject attempted to extend the knee, pressing the hips upward against a movable or immovable resistance.

Isometric muscular contraction. A muscular contraction in which tension was developed against a resistance that prohibited movement.

Isometric muscular strength. The degree to which a group of muscles exerted force through a contraction of the muscle fibers as measured by an isometric strength recording device.

Isotonic muscular contraction. A muscular contraction in which tension was developed against a resistance that allowed movement.

Isotonic muscular strength. The degree to which a group of muscles exerted force through contraction of the muscle fibers; measured by the ability to lift a specified weight a certain distance.

1-RM. One repetition maximum.[1] The maximum weight which could be moved the designated distance once only.

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[1]Richard A. Berger, "Determination of the Resistance Load for 1-RM and 10-RM," Journal of the Association for Physical and Mental Rehabilitation, XV (1961), 108.

CHAPTER II

REVIEW OF RELATED LITERATURE

I. INTRODUCTION

The comparative contributions of static contraction (isometric) exercise and progressive resistance (isotonic) exercise are a matter of concern to the physical education and physical rehabilitation professions. Although an affluence of research has been completed concerning their comparative effects, the controversial findings of this very research dictates that further investigations be conducted. The diversity of the findings is evident in the literature herein reviewed.

The concept that isometric exercise is capable of developing strength is certainly not new. Lorback[1] noted that from 1928 through 1930 there was a series of studies completed at Springfield College, Springfield, Massachusetts by Elbel,[2] Grunberg,[3]

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[1]Melvin M. Lorback, "A Study Comparing the Effectiveness of Short Periods of Static Contraction to Standard Weight Training Procedures in the Development of Strength and Muscle Girth" (micro-carded Master's thesis, Pennsylvania State University, 1955).

[2]Edwin R. Elbel, "A Study in Short Static Strength of Muscles" (unpublished Master's thesis, International Young Men's Christian Association College, Springfield, Massachusetts, 1928).

[3]Arthur A. Grunberg, "Short Static Contraction as an Aid in Corrective Gymnastics" (unpublished Master's thesis, International Young Men's Christian Association College, Springfield, Massachusetts, 1929).

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Labree,[4] and Hughes[5] regarding the effects of a short static muscular contraction on the development of strength. The findings of these studies indicated that strength could be increased by short static contraction exercise.

Rasch,[6] after an extensive review of the literature, attributes the findings of Hettinger and Muller,[7] published in 1953, as bringing the concept of isometric contraction exercise to its present prominence.

The work of Hettinger and Muller was reviewed by Steinhaus at the 1954 meeting of the College Physical Education Association. The following are their findings as reported at that meeting.

> Muscle strength increases an average of 5% per week when the training load is as little as 1/3 or even less, of maximum strength.
>
> Muscle strength increases more rapidly with increasing

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[4]Lawrence W. Labree, "A Study of Short Static Contractions as an Aid in the Department of Corrective and Remedial Gymnastics in Universities and Colleges" (unpublished Master's thesis, International Young Men's Christian Association College, Springfield, Massachusetts, 1930).

[5]Robert P. Hughes, "A Study in Short Static Strength of Muscles in Relation to Posture of School Boys" (unpublished Master's thesis, International Young Men's Christian Association College, Springfield, Massachusetts, 1930).

[6]Philip J. Rasch, "Progressive Exercise; Isotonic and Isometric: A Review," Journal of the Association for Physical and Mental Rehabilitation, XV (1961), 46.

[7]Th. Hettinger and E. A. Muller, "Muskelleistung and Muskeltraining," Arbeitsphysiologie, XV (1953), 111-16.

> intensity of training load up to about 2/3 of maximum strength. Beyond this, increase in training load has no further effect.
>
> One practice period per day in which the tension was held for six seconds resulted in as much increase in strength as longer periods (up to full exhaustion in 45 seconds) and more frequent practices (up to 7 per day).[8]

With the publishing of their findings regarding isometric contraction exercise, Hettinger and Muller opened up a whole new area of the strength development program. The next logical step was to investigate the effects of isometric exercise, not only on strength, but on other factors involved in fitness such as reaction time, speed of movement and endurance. A brief glance at the literature reveals that this course was taken.

The remainder of the chapter presents an extensive review of the literature pertaining to isometric contraction exercise. To facilitate comprehension in regard to the stated purpose of the study, the chapter is divided into the following sections: Strength Development, Dynamic Movement Improvement, Strength Specificity, and Training and Test Selection.

II. STRENGTH DEVELOPMENT

In 1960, after continued investigation, Hettinger[9] concluded

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[8]Arthur Steinhaus, The College Physical Education Association's 57th Annual Proceedings (New York City, 1954), 5-11.

[9]Theodor Hettinger, Physiology of Strength (Springfield, Illinois: Charles C. Thomas Co., 1961), p. 44.

that, "The maximum improvement in the strength of the muscle group being trained can be obtained by giving daily one maximum voluntary isometric muscle contraction against a resistance for one or two seconds." However, Berger[10] reported that a later study by Muller and Rohmert[11] found that a maximum contraction of from four to six seconds was more effective than a one second contraction.

Josehans[12] investigated the question as to how often and how long a muscle must contract isometrically in order for a maximal strength gain to occur. The muscle groups utilized were the grip muscles and the flexors and extensors of the index finger, elbow, and knee joint. He found that the number of contractions performed was significantly related to the strength of the muscle group in a logarithmic progression as more contractions are performed per unit time. It was also found that contractions of 25 per cent of the muscle force produced gains in muscle strength and that contraction duration time is of relatively minor importance.

The purpose of a study by Barham[13] was to compare the strength

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[10]Richard A. Berger, "Effects of Isometric Training," Physical Educator, XXII (1965), 81.

[11]E. A. Muller and W. Rohmert, "Die Geschwindgkeit der Muskelkroft-Zunahme bei Isometrischin Training," Arbeitsphysiologie, XIX (1963), 403-419.

[12]W. K. T. Josenhans, "An Evaluation of Some Methods of Improving Muscle Strength," Revue Canadienne de Biologie, XXI (1962), 315-323.

[13]Jerry N. Barham, "A Comparison of Two Methods of Isometric Exercise on the Development of Muscle Strength" (unpublished study, Louisiana State University, 1960).

gained by performing one daily six second isometric contraction to the strength gained by performing three daily six second isometric contractions. Fifty-five subjects were divided into three groups: Group I performed isometric contraction daily; Group II performed three contractions daily; and Group III acted as a control. The extensors of the leg and back were the muscle groups tested. Barham concluded:

1. Isometric exercise will result in significant improvements in muscle strength.
2. There is no significant difference between the strength gained by employing one isometric contraction daily and the strength gained by employing three daily isometric contractions.

In another study along similar lines, Barham[14] investigated the effectiveness of different frequencies of isotonic and isometric exercise. Three isometric and three isotonic groups were utilized with one group from each exercise method training five days a week, one group from each exercise method training three days a week, and one group from each exercise method training two days a week. The isometric contraction was held for six seconds in training while the isotonic routine was the maximum load that could be lifted five times

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[14]Jerry N. Barham, "A Comparison of the Effectiveness of Isometric and Isotonic Exercises When Performed at Different Frequencies per Week" (unpublished Doctoral dissertation, Louisiana State University, 1960).

plus the same isometric training program previously described. Barham reported the following findings:

1. A significant improvement in strength was achieved by the three isometric groups.
2. The addition of isotonic exercise to the isometric routine did not bring about a significantly greater gain in strength.
3. There was not a significant difference in the strength gained by exercising five days a week and exercising three days a week.
4. There was a significantly greater gain in strength by the group exercising five days a week over the group exercising two days a week.

In 1955 Lorback[15] reported a study in which he compared the effectiveness of a six second, two-thirds maximum isometric contraction to a standard weight training program in developing strength. Two groups of thirty subjects each were used: one group performing isometric contraction exercise and the other group participating in a standard weight training program. The muscle groups tested were those involved in hand grip, neck flexion, elbow flexion and extension, and knee flexion and extension. Eight weeks of training was performed with new two-thirds maximum strength loads being computed after four weeks.

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[15]Lorback, loc. cit.

Lorback found that both methods were approximately equal in the amount of strength gained by the subjects. He also found that both groups made significant gains in muscle girth with no significant difference being found between the gains of the two groups.

Salter[16] reported similar findings and concluded that isotonic and isometric exercise brought about an improvement of muscle strength with no significant difference between the gains in strength occurring from the two exercise methods.

Petersen,[17] using twenty-four females and twenty-three males, found that one maximum isometric contraction performed daily for thirty-six days would not increase isometric strength in positions of approximately 90° elbow flexion and 90° knee extension. In most cases, however, the males did make gains (significance not computed) while the females either lost or stayed the same and since final figures were from groupings, the results may not have been indicative of the individual differences between sexes.

In 1959 Asa[18] trained the abductor digiti quinti muscles of

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[16]Nancy Salter, "The Effect on Muscle Strength of Maximum Isometric and Isotonic Contractions at Different Repetition Rates," Journal of Physiology, CXXX (1955), 113.

[17]Flemming B. Petersen, "Muscle Training by Static Concentric and Eccentric Contractions," ACTA Physiologica Scandinavica, XLVIII (1960), 406-416.

[18]Maxim M. Asa, "The Effects of Isometric and Isotonic Exercise on the Strength of Skeletal Muscle" (unpublished Doctoral dissertation, Springfield College, Springfield, Massachusetts, 1959).

two groups of subjects. One group trained isotonically for a period of twelve weeks. The second group trained with a daily six second isometric contraction for nine weeks and the group was divided with one group continuing the same routine for three additional weeks. The other half of the isometric group performed twenty isometric contractions per day for the additional three weeks.

Asa found that both isotonic and isometric training groups exhibited significant increases in strength. Also, the group exercising once daily exhibited a greater increase in strength than the group utilizing isotonic exercise and those performing twenty isometric repetitions per day for the last three weeks showed the greatest gain in strength.

Berger[19] divided seventy-eight subjects into two groups, with one group training isometrically and one group training isotonically three times a week for twelve weeks. All subjects were tested both isometrically and isotonically for lower back extensor strength. Both groups improved significantly on both tests, however, the isometric group showed greater improvement when measured isometrically than when measured isotonically and the isotonic group exhibited greater improvement when measured isotonically than when measured isometrically. Berger concluded that isometric strength was best

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[19]Richard A. Berger, "Comparison of Static and Dynamic Strength Increases," Research Quarterly, XXXIII (1962), 329-333.

measured isometrically and isotonic strength was best measured isotonically.

After training fifty-seven college males statically, three times a week for twelve weeks as opposed to 177 college males with various dynamic programs, Berger[20] found no significant difference in strength improvement between the two groups as wholes. He did find that the sub-group which trained dynamically for three bouts and six repetitions per bout did exceed the sub-group trained statically in strength improvement, but he also found that the sub-group trained dynamically for two bouts and two repetitions was inferior to the sub-group trained statically.

Bergeron[21] did a study in which he compared weight training to isometric exercise in developing strength and muscle girth. Forty subjects were divided into two groups—one group performing a static contraction for six seconds once per training period and the other group undergoing a weight training program. Both groups exercised three times a week for ten weeks. The muscle groups being exercised were those extending the lower arm, those flexing the leg, and those extending the leg. Bergeron found:

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[20] Richard A. Berger, "Comparison Between Static Training and Various Dynamic Training Programs," Research Quarterly, XXXIV (1963), 131-135.

[21] Philip C. Bergeron, Jr., "A Comparison of the Effectiveness of Systematic Weight Training and Isometric Exercise in the Development of Strength and Muscle Girth" (unpublished study, Louisiana State University, 1963).

1. There was a significant gain in muscle girth by both groups but a significant difference was not found between the two groups.
2. Both groups gained significantly in strength measured by both methods of testing; weight lifting and isometric testing.
3. The isometric group showed a greater mean gain in strength development when measured by an isometric strength measuring device but the difference between these gains and those of the isotonic group when measured isometrically was not significant.
4. The isotonic group showed a greater mean gain in strength development as measured with weights, but the difference between these gains and those of the isometric group when measured with weights was significant in only the supine press and then at the .05 level of confidence.

Kruse[22] divided one hundred eight college males into eight groups, four doing isometric training and four doing isotonic training. One group from each type of training exercised two, three, four or five times a week. The isometric group performed three, six-second contractions at each training session. Kruse found

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[22]Robert D. Kruse, "The Effects of Varying Frequencies of Training Sessions upon the Strength of the Elbow-Flexor Muscle Group" (microcarded Doctoral dissertation, Springfield College, Springfield, Massachusetts, 1956).

that both the isometric and isotonic sections showed a significant gain in strength but that there was no significant difference between the gains of the groups. After reviewing the individual scores, the author reported that "it would appear that the amount of strength gain in any exercise program was dependent upon the individual participating rather than the frequency or type of exercise itself."

The purpose of a study by Marley[23] was to compare isometric and isotonic training in their effectiveness to develop muscular strength, endurance, and girth. An isometric training group, an isotonic training group and a control group were utilized. He concluded:

1. Both training programs brought about an increase in strength with little difference existing between the two.
2. Isometric endurance and isotonic endurance are developed more effectively by isometric training and isotonic training, respectively.

In another comparison of the effects of isometric and isotonic exercise, Matthews and Kruse[24] concluded that isometric contraction exercise brought about a significant strength gain in

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[23]William P. Marley, "The Comparative Effectiveness of Isometric Exercise and Isotonic Exercise in the Development of Muscular Strength, Endurance, and Girth" (microcarded Master's thesis, University of Maryland, 1962).

[24]Donald K. Matthews and Robert Kruse, "Effects of Isometric and Isotonic Exercise on Elbow Flexor Muscle Groups," Research Quarterly, XXVIII (1957), 26-37.

more subjects than did isotonic exercise. They further concluded that strength gains were peculiar to the individual.

Meadows[25] at the University of Illinois in 1959 reported no difference in the strength gains produced by isometric and isotonic training procedures. Both methods did result in significant strength gains between initial and final tests.

Rasch and Morehouse[26] trained two groups of subjects, one isometrically and one isotonically, three days a week for six weeks. They utilized tests which employed the trained muscles in both a familiar way and an unfamiliar way. Although strength gains were shown in the familiar procedure, little or no gains were recorded in the unfamiliar procedure. From these observations, they stated that, "The findings suggest that the higher scores in strength tests resulting from exercise programs reflected largely the acquisition of skill." Also, the group training isotonically showed greater gains in strength and hypertrophy than did the isometric group.

In another study, Rasch[27] trained a group isotonically for six weeks and then tested them both isotonically and isometrically.

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[25]Paul Meadows, "Effect of Isotonic and Isometric Muscle Contraction Training on Speed, Force and Strength" (unpublished Doctoral dissertation, University of Illinois, 1959).

[26]Philip J. Rasch and L. E. Morehouse, "Effect of Static and Dynamic Exercises on Muscular Strength and Hypertrophy," Journal of Applied Physiology, XI (1957), 29-34.

[27]Philip J. Rasch, "Relationship Between Maximum Isometric Tension and Maximum Isotonic Elbow Flexion," Research Quarterly, XXVIII (1957), 85.

Upon comparison of the isometric and isotonic strength scores he concluded that "measurements of maximum strength made by use of isometric techniques are valid in expressing isotonic strength."

In a later study, Rasch and Pierson[28] determined the effect of isotonic exercise on isotonic and isometric strength. Although there was a significant gain noted after six weeks in the isotonic strength of the group there was not a significant gain in the isometric group.

Rasch and Pierson[29] further investigated the relationship between isotonic and isometric scores after a weight training program of six weeks. They found that isotonic strength improvement was not reflected by isometric strength improvement. They suggest that if the converse was also found to be true, the value of isometric exercise in preparing for isotonic activities must surely be questioned.

Dickinson[30] compared two methods of isotonic exercise to one method of isometric exercise on strengthening the extensor muscles of the leg. He concluded that all methods were equally effective in

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[28]Philip J. Rasch and W. R. Pierson, "Isotonic Training and Isometric Strength," Perceptual Motor Skills, XVI (1963), 229-230.

[29]Philip J. Rasch and W. R. Pierson, "Some Relationships of Isometric Strength, Isotonic Strength, and Anthropometric Measures," Ergonomics, VI (1963), 211-215.

[30]Arthur L. Dickinson, "Resistance-Exercise for Development of Strength of Muscles that Extend Leg at Knee: A Comparative Study of Three Methods" (unpublished Doctoral dissertation, State University of Iowa, 1963).

bringing about strength gains over a twelve week training period.

The findings of the studies reviewed above serve to point up the disparity existing in the research pertaining to the relative merits of isometric and isotonic exercise. Although most of the studies indicated that both isometric and isotonic training will bring about significant increases in strength, there were individual studies which found that isometric exercise would not increase strength, that isometric was better than isotonic exercise for increasing strength, that isotonic exercise would not increase isometric strength, and that isometric exercise was better for increasing isometric strength and isotonic exercise was better for increasing isotonic strength.

Other conflicting findings were in the number of days per week necessary for maximum strength gain, the length of the contractile effort, the strength of the contractile effort, and the number of repetitions which should be used each training session.

The literature would seem to reveal that the minimum training requirements for isometric strength gains would be a single, six second maximum contraction performed three days a week.

III. DYNAMIC MOVEMENT IMPROVEMENT

This section deals primarily with studies investigating the relative merits of isometric and isotonic exercise in improving

such factors as cardiovascular endurance, muscular endurance, speed of movement, reaction time, and explosive force.

Utilizing 240 male college students, Alost[31] compared the effects of isometric exercise to running on cardiovascular condition as measured by the Harvard Step Test. He found no significant difference in the effectiveness of isometric exercise and running in the development of cardiovascular endurance. However, he did find that there was a direct relationship between frequency of practice periods and improvement in strength, running performance, and cardiovascular condition.

Howell, Kimoto, and Morford[32] equated three groups of eleven boys on a bicycle ergometer test. One group trained with weights, one group trained with a six second isometric contraction and the other group was the control. Exercises were taken twice a week for eight weeks. Both exercise groups made significant gains on the bicycle ergometer test at the .01 level of confidence. No significant difference was found between the means of the difference between the initial and final scores of the two exercise groups.

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[31]Robert A. Alost, "A Study of the Effect of Initial Cardiovascular Condition, Type of Training Program and Frequency of Practice Periods upon the Cardiovascular Development of College Men" (unpublished Doctoral dissertation, Louisiana State University, 1963).

[32]Maxwell L. Howell, Roy Kimoto and W. R. Morford, "Effect of Isometric and Isotonic Exercise Programs upon Muscular Endurance," Research Quarterly, XXXIII (1962), 536-540.

Two equated groups of ten subjects were used in a study by Dennison, Howell and Morford[33] to determine the effects of a weight training program and an isometric training program on muscular endurance. Muscular endurance was measured by dipping repetitions, chinning repetitions and the Arm Strength Index. Subjects exercised twice a week for six weeks. The authors found significant gains at the .01 level for dips in the weight training group. The isometric group showed significant gains at the .05 level for all tests. The weight training group exercised thirty minutes a day while the isometric group exercised only ten minutes a day. There was not a significant difference between mean improvements of the two groups, thus indicating that one method was as effective as the other.

Chui[34] investigated the comparative effects of isometric and isotonic exercise on strength and speed of movement. Seventy-two subjects were divided into four groups: Group I was isometric, Group R was rapid dynamic contraction, Group S was slow dynamic contraction, and Group C was the control. Strength was measured statically. Chui found that there were significant gains in

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[33]J. D. Dennison, M. L. Howell and W. R. Morford, "Effects of Isometric and Isotonic Exercise Programs upon Muscular Endurance," Research Quarterly, XXXII (1961), 348-52.

[34]Edward F. Chui, "Effects of Isometric and Dynamic Weight-training Exercises upon Strength and Speed of Movement," Research Quarterly, XXXV (1964), 246-257.

strength and speed of movement times with and without resistance in Groups I, R, and S while there were no significant differences in the gains made between groups. Therefore, within the limits of the study, isometric and isotonic exercise were equally effective in bringing about strength gains and speed of movement gains.

Pierson and Rasch[35] investigated the effects of isotonic exercise on strength, reaction time, and speed of movement. They found significant increases in strength but corresponding increases in speed of movement and reaction time were not indicated.

It was the purpose of another study by Pierson and Rasch[36] to investigate the correlation of isometric strength to isotonic endurance, reaction time, and speed of movement. The subjects were tested isometrically and one week later were tested for isotonic endurance, speed of movement, and reaction time. No significant correlation was found between isometric strength and any of the factors measured.

Henry and Whitley[37] also investigated the correlation between static strength and "strength in action" computed from arm mass and

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[35]W. R. Pierson and P. J. Rasch, "Strength and Speed," Perceptual and Motor Skills, XIV (1962), 144.

[36]W. R. Pierson and P. J. Rasch, "Isometric Strength as a Factor in Functional Muscle Testing," American Journal of Physical Medicine, XLII (1963), 205-207.

[37]Franklin Henry and J. D. Whitley, "Relationship Between Individual Differences in Strength, Speed, and Mass in an Army Movement," Research Quarterly, XXXI (1960), 24.

speed of movement. They found no significant correlation between the two types of strength and further state that, "The results agree with the concept that strength as ordinarily measured is determined by a neuromotor coordination pattern rather than the ultimate physiological capacity of the muscle. The neuromotor pattern energizing the muscle is different during movement."

Michael[38] utilized four groups of thirty-four college males to determine the effect of isometric exercise on arm and leg movement time and arm and leg reaction time. Group I served as a control, Group II performed isometric exercises, Group III participated in a fundamental softball program, and Group IV performed isometric exercises in addition to a softball program. Michael found that a six week program of isometric exercise significantly increased speed of movement time and reaction times whereas the addition of softball to isometrics resulted in no significant gain and softball alone did not result in a change in reaction and movement time.

Sixty-three college males were divided into two equated groups by Ball, Rich and Wallis[39] in order to investigate the

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[38]Charles E. Michael, "The Effects of Isometric Contraction Exercises on Reaction and Speed of Movement Time" (unpublished Doctoral dissertation, Louisiana State University, 1963).

[39]Jerry R. Ball, George Q. Rich and Earl L. Wallis, "Effects of Isometric Training on Vertical Jumping," Research Quarterly, XXXV (1964), 231-235.

effects of isometric exercise on vertical jumping ability. One group performed a ten second maximum contraction three times a week for six weeks. The other group served as the control. The experimental group significantly increased in isometric strength but there was not an accompanying increase in vertical jumping ability.

In a somewhat similar study, Berger[40] utilized four groups: Group I trained isotonically with the 10-RM, Group II trained with 50 per cent to 60 per cent of the 10-RM for ten repetitions of squat jumps, Group III trained isometrically, and Group IV trained by jumping vertically. Vertical jumping ability was measured before and after a seven week training period. Berger found:

1. Groups I, II, and III differed significantly from Group IV in jumping ability.
2. Only Groups I and II improved significantly in vertical jumping ability.
3. Groups I and II increased significantly more in jumping ability than Group III but Groups I and II did not differ significantly.

IV. STRENGTH SPECIFICITY

The studies reviewed in this section are concerned in some manner with specificity of strength gains brought about by isometric

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[40]Richard A. Berger, "Effects of Dynamic and Static Training on Vertical Jumping Ability," Research Quarterly, XXXIV (1963), 419-424.

or isotonic exercise. Although this was not the expressed purpose of all the studies reviewed, they do have implications for the identification of specificity.

Richardson[41] investigated the effects of isometric and isotonic training on the elbow flexor muscle group. The isometric group trained at angles of 90°, 135°, and 165° elbow flexion daily for five weeks. The isotonic group completed three daily lifts in six seconds (same length of time as the isometric contraction) with a maximum weight traversing an arc of 90° to 165°. The third group was the control. Richardson found:

1. Both groups increased significantly at 115° and 135° over the control group.
2. The isotonic group increased significantly at 135° over the isometric group.

Rasch, Pierson and Logan[42] tested ten adult males isometrically at 45°, 90°, and 135° of elbow extension. The subjects then trained with three, 15 second maximum exertions three days a week for six weeks in 90° elbow flexion. Upon retesting it was found that the extensor muscles made significant gains at all three

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[41] John R. Richardson, "The Effect of Brief Isometric and Isotonic Exercise Programmes on the Development of Strength and Muscular Endurance" (unpublished Master's thesis, University of Alberta, 1963).

[42] P. J. Rasch, W. R. Pierson and Gene A. Logan, "The Effect of Isometric Exercise upon the Strength of Antagonistic Muscles," Internationale Zeitschrift Fur Angewandte Physiologie Einschliesslich Arbeitsphysiologie, XIX (1961), 18-22.

positions with no significant difference between positions. The authors suggest that "under conditions of super maximal isometric contraction of elbow flexor muscles, co-contraction of the antagonistic muscles is necessary to fix and stabilize the joint, and that the degree of effort required of these muscles is sufficient to produce an increase in their strength." They also suggest that the strength thus developed tends to increase to the same degree throughout the arc involved in the movement.

Although this study investigated the specificity of strength gains in the antagonistic muscles it would seem logical that the results would hold true in the muscles actually responsible for the force being exerted. Not all of the following studies back up this assumption.

In a study by Darcus and Salter[43] it was found that static training in only one position of the range of motion of a joint resulted in an increase of strength at all other statically tested positions within the same range of motion. Subjects were tested both isometrically and isotonically at the start and finish of the study. Both groups exercised five days a week for five weeks; one group of six subjects exercised statically and the other group of six exercised dynamically. It was further concluded that both static and dynamic strength were increased after either static or dynamic exercise.

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[43]H. D. Darcus and Nancy Salter, "The Effect of Repeated Muscular Exertion on Muscle Strength," Journal of Physiology, CXXIX (1955), 325-336.

Contrary to the above findings, Gardner[44] found no significant strength improvements at any angle other than the angle at which the exercise was performed. Gardner utilized sixty subjects divided into four groups. Group I was the control group and did not exercise, Group II exercised the preferred leg at a 115° angle of knee extension, Group III exercised at a 135° angle of knee extension, and Group IV exercised at a 155° angle of knee extension. The subjects in Groups II, III, and IV performed one six-second, two-thirds maximum isometric effort three days a week for six weeks. Subjects were tested on a cable tensiometer before the training period and every two weeks thereafter in order to compute new two-thirds training loads. Group III and Group IV showed significant strength gains at the position of exercise but not at the other angles tested. Group II showed no significant strength gain at any specific angle.

Logan[45] utilized three groups of fifteen subjects each and determined static strength by means of a cable tensiometer at angles of 95°, 115°, 135°, 155°, and 175° of knee extension. Group I performed a weight resistance program for thirteen periods in six weeks with the greatest amount of resistance being offered at approximately 155°. Group II performed strengthening exercises in

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[44]Gerald W. Gardner, "Specificity of Strength Changes of the Exercised and Nonexercised Limb Following Isometric Training," Research Quarterly, XXXIV (1963), 98-101.

[45]Gene A. Logan, "Differential Applications of Resistance and Resulting Strength Measured at Varying Degrees of Knee Extension" (unpublished Doctoral dissertation, University of Southern California, 1960).

the same manner except using spring resistance with the greatest resistance being offered at 115°. Group III was the control. He found:

1. At the .01 level of confidence, both Groups I and II showed significant strength gains at all angles over Group III.
2. Significant strength gains were made by Group II over Group I at 115°.
3. Significant strength gains were made by Group I over Group II at 155°.
4. There was no significant difference when strength gains at 135° were compared for Groups I and II.

It was the purpose of a study by Sterling[46] to investigate the specificity of strength gains achieved through isometric contraction exercise in the elbow flexors, knee flexors, and knee extensors. Two groups of college males were administered pre- and post-study strength tests at 95° and 170° in the three ranges of motion. One group trained isometrically at 95° elbow flexion, 170° knee flexion and 170° knee extension while the other group trained at 170° elbow flexion, 95° knee flexion and 95° knee extension. The exercise routine was an eight second maximum

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[46]Duane R. Sterling, "A Comparative Study of the Position Selectivity of Isometric Strength Changes Resulting from Isometric Exercise" (unpublished Master's thesis, Louisiana State University, 1964).

isometric contraction performed three days a week for ten weeks. Sterling found:

1. In the elbow flexor muscle group, significant gains were exhibited only at the position of exercise.
2. In the knee extensor muscle group, significant gains were exhibited at both 95° and 170° regardless of the position of exercise.
3. In the knee flexor muscle group, significant gains were exhibited at 170° when exercise was at 95° and when exercise was at 170° significant gains were made at both 95° and 170°.

These findings would seem to point to the possibility that specificity of strength gains produced by isometric exercise varies as to the muscle group being tested. The elbow flexor group was highly specific at the position of exercise while the knee flexor group appeared to exhibit specificity at a position other than the position of exercise. The knee extensor muscle group exhibited little specificity of strength gains.

In a follow-up study on the knee flexor muscle group, Sterling[47] repeated the conditions of the parent study. This time eighteen college males were divided into two groups: one group

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[47]Duane R. Sterling, "A Comparative Study of the Specificity in Position Selectivity of Isometric Strength Changes in the Knee Flexor Muscle Group Resulting from Isometric Exercise: A Restudy" (unpublished study, Louisiana State University, 1964).

exercising at 170° and the other at 95°. At the end of the ten weeks training period, exercise at 95° had not significantly increased strength at either 95° or 170° while exercising at 170° had significantly increased strength only at 170°. Upon comparing these results to the results of the parent study, Sterling concluded that the muscle group causing knee flexion shows no definite specificity of strength gains.

The disparity in the findings of the studies reviewed in this section points to the need for continued research into the matter of specificity of strength gains. It appears logical to assume that strength specificity, either the presence or absence thereof, is the key to whether or not strength achieved isometrically can be effectively utilized in dynamic movement.

V. TRAINING AND TEST SELECTION

The studies reviewed in this section are concerned with determining the most efficient and practical methods by which to conduct the training and testing program. The results of these investigations as well as those previously reviewed are intended to insure that the data received from the proposed study will not be biased in some manner due to improper selection of testing and training methods.

Isotonic Testing and Training

The purpose of a study by Berger[48] was to determine the optimum number of repetitions which would bring about the quickest strength improvement. Groups utilizing the 2-RM, 4-RM, 6-RM, 8-RM, 10-RM, and 12-RM resistance for one set, three days a week for twelve weeks were compared in strength gains. He found that groups utilizing the 2-RM, 10-RM, and 12-RM had significantly smaller mean gains than the groups utilizing the 4-RM, 6-RM, and 8-RM load. From these results he concluded that the optimum number of repetitions was between three and nine.

Berger[49] utilized nine different isotonic training programs to determine the most effective combination for improving strength. All possible combinations of two, six, and ten repetitions and one, two, and three sets were investigated with all subjects training three times a week for twelve weeks. Strength was measured isotonically by the 1-RM method. All of the training methods produced significant gains at each three week interval. However, the statistical analysis showed that three sets brought about a significantly greater improvement than either one or two sets with no significant difference found between the latter two methods. Six

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[48]Richard A. Berger, "Optimum Repetitions for the Development of Strength," Research Quarterly, XXXIII (1962), 334-338.

[49]Richard A. Berger, "Effect of Varied Weight Training Programs on Strength," Research Quarterly, XXXIII (1962), 168-181.

repetitions per set brought about significantly greater improvement than two repetitions but not ten repetitions. The results suggest that three sets and six repetitions per set is the best combination for improving strength.

In another study, Berger[50] investigated which proportions of the 1-RM would be as effective for increasing strength as training with the 1-RM itself. The proportions were 66 per cent, 80 per cent, and 90 per cent. All subjects trained three times weekly for six weeks. He found that the groups training with 66 per cent, 80 per cent, and 90 per cent of the 1-RM, when the 1-RM was determined once weekly, and the groups training with the 1-RM either once or three times weekly made significant gains but did not differ significantly in strength gains. The control group and the group utilizing 66 per cent of the 1-RM (but not determining the 1-RM weekly) did not make significant gains.

Yessis[51] investigated the effects of varying resistances and numbers of repetitions on strength and muscular endurance. One group trained using the 1-RM, a second group trained using the 8 to 12-RM, a third group trained using a fixed resistance for a maximum

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[50]Richard A. Berger, "Comparison of the Effect of Various Weights Training Loads on Strength," Research Quarterly, XXXVI (1965), 141-[illegible] Michael

[51]Michael Yessis, "Relationships Between Varying Combinations of Resistances and Repetitions in the Strength-Endurance Continum" (microcarded Doctoral dissertation, University of Southern California, 1963).

number of repetitions, and the fourth group trained using a fixed resistance for two-thirds of a maximum number of repetitions. He concluded that if strength was the goal the training program should be with a maximum or near maximum resistance and few repetitions. If endurance is the objective then the training should stress maximum or near maximum repetitions at a constant resistance.

The purpose of a study by Hansen[52] was to investigate the effects of dynamic maximal resistance exercise on such factors as isometric strength, isometric endurance and work capacity. Two groups of males were tested for isometric strength, dynamic strength (1-RM), working capacity (endurance), and isometric endurance (ability to hold 60 per cent of 1-RM for as long as possible at 90°). One group trained six days a week for five weeks by performing ten repetitions of the 1-RM in two sessions with at least a thirty second pause between repetitions. The other group served as a control. The left elbow flexors was the muscle group trained. A new 1-RM was computed the first day of each week. He found a significant difference between the groups in both isometric and dynamic strength and working capacity. The results of this study were compared to that of another study in which only 60 per cent of the 1-RM was used in training and no significant increases were

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[52]Jorgen W. Hansen, "The Training Effect of Dynamic Maximal Resistance Exercise," Internationale Zeitschrift Fur Angewandte Physiologie Einschliesslich Arbeitsphysiologie, XIX (1963), 420-424.

found. From the comparison he concluded that "maximal tensions are essential for developing the isometric strength of a muscle, while dynamic muscle contractions with sub-maximal load do not seem to affect the isometric strength to a considerable degree. . ."

Klein[53] has found that the deep squat exercise used in physical conditioning and weight training programs is injurious to the knee joint and he has stated that it "should be discouraged from the standpoint of its debilitative effect on the ligamental structures of the knee."

On the other hand, Drury and Townley[54] conducted a survey to determine the effect of deep squats upon the knee of athletes during and after the competitive period and then compared these results with a survey of non-athletes on the condition of the knee joint. They concluded that "from these observations the deep knee bend exercise will have neither a temporary nor permanent harmful effect on the knee." They further concluded that their observations indicated "that this type of exercise can be an important factor in the prevention of injury to the knee and in maintaining a knee from aches and pains in later life."

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[53]K. K. Klein, "The Deep Squat Exercise as Utilized in Weight Training for Athletics and its Effect on the Ligaments of the Knee," Journal of the Association for Physical and Mental Rehabilitation, XV (1961), 6.

[54]Francis A. Drury and J. A. Townley, "The Effects of the Deep Knee Bend, or 'Squat' Exercises, Upon the Knees" (unpublished study, Louisiana State University).

Pierson summarizes P. J. Rasch's statements at a symposium on weight training and athletics with the following statements.

> The basic principles involved in any weight training program: (a) the overload principle, (b) fatigue is normal and it is necessary that it be experienced, (c) the exercise must be progressive in nature, (d) with the possible exception of the knee joint, exercises should be made through the entire range of movement, (e) rest pauses should be taken between exercises or sets of exercises, (f) workouts should be at regular intervals, and (g) the exercise should be as specific to the specialty of the athlete as possible.[55]

Isometric Testing and Training

Numerous studies have been reviewed concerning isometric testing and training in the section of this chapter title Strength Development (pages 8-19). Only supplementary articles of additional interest will be reviewed in this section.

It was the purpose of a study by Lindeburg[56] to determine the most efficient angle at which a maximum muscular effort could be achieved in the inverted leg press. Thirty-seven high school boys were tested at angles of the leg on the thigh of 100°, 110°, 120°, 130°, and 140°. These angles were chosen because a previous study had determined that at angles of 90° or less and 150° or more the muscles could not operate at maximum efficiency. "The angle

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[55]William R. Pierson, "In New Directions in Weight Training and Athletics--Report of a Symposium," Journal of the Association for Physical and Mental Rehabilitation, XV (1961), 114-115.

[56]Franklin A. Lindeburg, "Leg Angle and Muscular Efficiency in the Inverted Leg Press," Research Quarterly, XXXV (1964), 179-183.

between the leg and thigh was measured with a protractor to the nearest 10°. The protractor was placed at the malleolus bone on the ankle, the head of the tibia on the knee, and the middle of the thigh." He found no significant difference between the strength at any of the angles tested and concluded that muscular efficiency throughout the middle range of knee joint extension is more or less general.

Kroll[57] investigated the effects of five, ten, and fifteen repetitions in bouts of five each upon criterion strength measures taken two weeks later. Three groups were matched on the basis of the initial right wrist flexor strength and were given one, two, and three sessions, respectively, each of five trials. Two weeks later the groups were tested in the same manner under the same conditions. The author found no significant differences for any of the test-retest situations. Also found was that the absolute level of strength did not vary with the number of trials given. Based upon these findings, Kroll concluded that trial variance on the first day did not significantly affect the criterion strength measures in the retest situation two weeks later.

Marcel[58] used sixty male subjects in the seventh grade and

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[57]Walter Kroll, "A Reliable Method of Assessing Isometric Strength," Research Quarterly, XXXIV (1963), 350-355.

[58]N. A. Marcel, "The Effect of Knowledge of Results as a Motivation on Physical Performance" (unpublished study, Louisiana State University, 1961).

divided them into two groups of thirty each. Subjects performed six isometric exercises three times a week for six weeks. One group was told their daily scores while the other group did not know the progress they were making. The author found that both groups made significant gains in strength which would indicate that a three day a week, once a day, six second isometric contraction in forearm flexion, leg flexion, and leg extension would produce strength gains. The group having knowledge of their progress had a greater mean of gains than those not knowing their daily scores.

CHAPTER III

PROCEDURE

I. OVERVIEW OF PROCEDURES

One hundred twenty male undergraduate students enrolled in the required physical education activity classes of badminton, volleyball, archery, tennis, and introduction to physical activity at Central Missouri State College, Warrensburg, Missouri were used as subjects. The subjects were randomly assigned to five groups of twenty-four subjects each on the basis of activity class enrollment with four subjects from archery, five from volleyball, six from badminton, four from tennis, and five from introduction to physical activity comprising each group. In this way any bias was eliminated that might occur due to enrollment in a particular activity. Students who were participating in an extraclass conditioning program, students in a restricted activity program due to a physical impairment, and varsity athletes were excluded from the study.

All subjects underwent a one week familiarity program which included practice with all of the tests and training procedures utilized in the study. The 120 subjects were then tested at 95°, 125°, and 155° angles of the leg on the thigh in the isometric hip press (utilizing both legs). Also tested were the isotonic hip press (utilizing both legs) and vertical jumping ability. Specific

groups received retests in isometrics, isotonics and vertical jumping ability to determine the reliability of the testing procedure.

After the initial testing, the 120 subjects were divided into the five training groups, and the individual groups began the following three day a week, seven weeks training program in conjunction with the physical education class. Group I trained in the isometric hip press at a 95° angle of the knee; Group II trained in the isometric hip press at a 125° angle of the knee; Group III trained in the isometric hip press at a 155° angle of the knee; Group IV trained isotonically in the hip press through a 90° range of motion beginning at a 90° angle of the knee and continuing to the lockout position; and Group V served as the control group, participating only in the scheduled physical education class.

During the seventh week of training all groups repeated the familiarity program and continued their assigned training routine. Upon completion of the seven week training program all subjects repeated the initial testing procedure.

II. FAMILIARITY PROCEDURE

The initial week of the study served not only to familiarize the subjects with the testing and training procedures but also better acquainted the assistant testers with the procedures to be followed. The familiarity program was adopted in an attempt to eliminate, as much as possible, the gains recorded between groups due to practice

in the testing procedure, which would not be an actual representation of increased muscular strength. The subjects, upon reporting to class, proceeded to one of five stations; the three isometric stations, the isotonic station or the vertical jumping station. Subjects rotated from station to station until all three procedures were practiced.

The isometric familiarity procedure consisted of one maximum isometric contraction at each angle (95°, 125°, and 155°) under test conditions.

The isotonic familiarity procedure consisted of utilizing a relatively light resistance (body weight) for ten to twenty repetitions on the first day, the 6-RM to 10-RM on the second day, and the 1-RM to 2-RM on the last day. The isotonic test conditions were adhered to with the exception of the weight used on the first two days.

The vertical jumping familiarity procedure consisted of five maximum jumps under test conditions.

The seventh week familiarity procedure was identical to the first week with the exception that the isotonic group continued their training routine rather than repeat the isotonic familiarity routine.

III. TESTING PROCEDURE

Isometric

All subjects were tested initially and finally in an isometric hip press exercise at 95°, 125° and 155° angles of the leg on the

thigh. Groups I, II, and III were retested on the day following the initial test at 95°, 125°, and 155° angles respectively for a reliability check of the testing procedure. The equipment used in isometric testing was two Iso-scales, one leg dynamometer, three footboards, and three pre-stretched nylon web belts. Also, three goniometers and a stop watch were utilized. Three assistant testers, one at each of three testing stations aided in administering the tests.

The angle of the leg on the thigh was determined by placing one arm of a goniometer on the lateral malleolus, the axis on the lateral surface of the lateral condyle of the tibia, and the other arm of the goniometer along the frontal midline of the thigh. Once the belt loop which provided the desired angle for each subject was determined, further measurements were unnecessary. Figure I presents a photograph of the angle determination procedure.

A stop bar for the heel was secured to each footboard in order that every subject was positioned identically with respect to every other subject. This insured the same angle of pull around the bearing leading to the Iso-scale.

The position to be assumed by the subject was with the desired angle of the leg on the thigh while the back was parallel with the floor. The belt was positioned over the lower three lumbar vertebrae. The subject was instructed to keep the heels on the floor at all times and the assistant tester steadied the subject if loss of balance

FIGURE 1

ANGLE DETERMINATION PROCEDURE

occurred. Figure 2 presents a photograph of the isometric testing procedure.

The subject was instructed to gradually build to maximum exertion rather than to "explode" into the belt. A maximum contraction was exerted for ten seconds during which time the assistant tester verbally encouraged the subject to put out a maximum effort. The score thus achieved was recorded as the maximum isometric contraction for the individual at that angle.

An angle was tested by the same scale throughout the duration of the study. The head tester gave a brief orientation to all subjects. Then all of the subjects in a particular activity were tested at one angle and when tests at that angle were completed, all subjects proceeded to the next angle utilizing the same testing order. The order in which the angles were tested was alternated with each activity group to exclude any possible effect that prior testing might have on subsequent testing. Each assistant tester was responsible for the correct angle for each individual by use of the goniometer. When a subject was properly positioned, a signal was given to begin the ten second maximum effort and a second signal to stop was given at the end of the ten second period. This continued until the entire activity group was tested at this one angle.

Isotonic

All subjects were tested initially and finally in an isotonic hip press exercise to determine the maximum resistance which could be

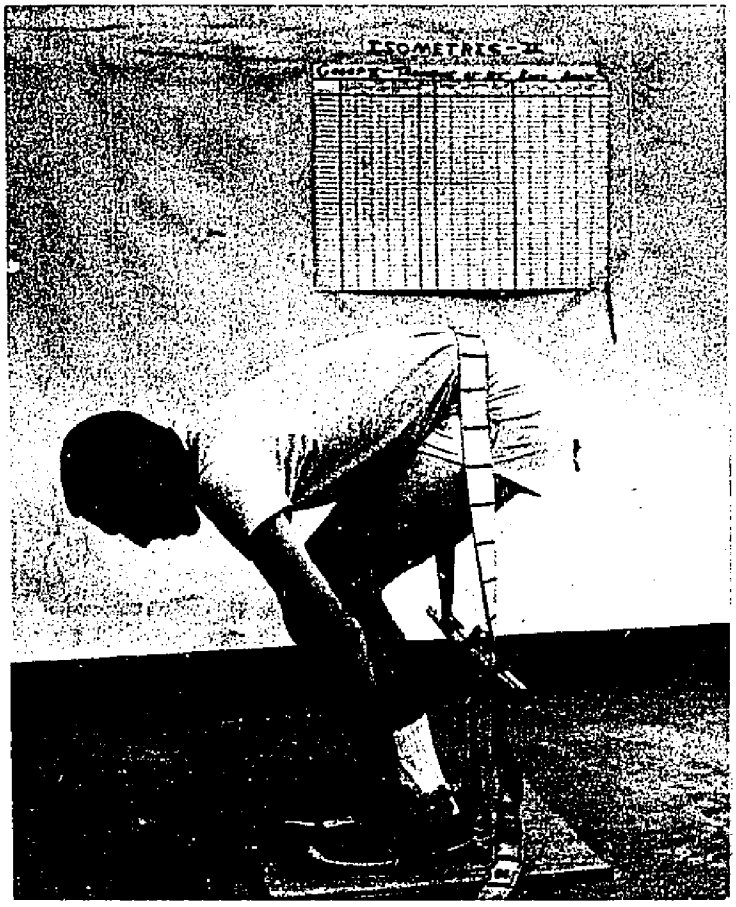


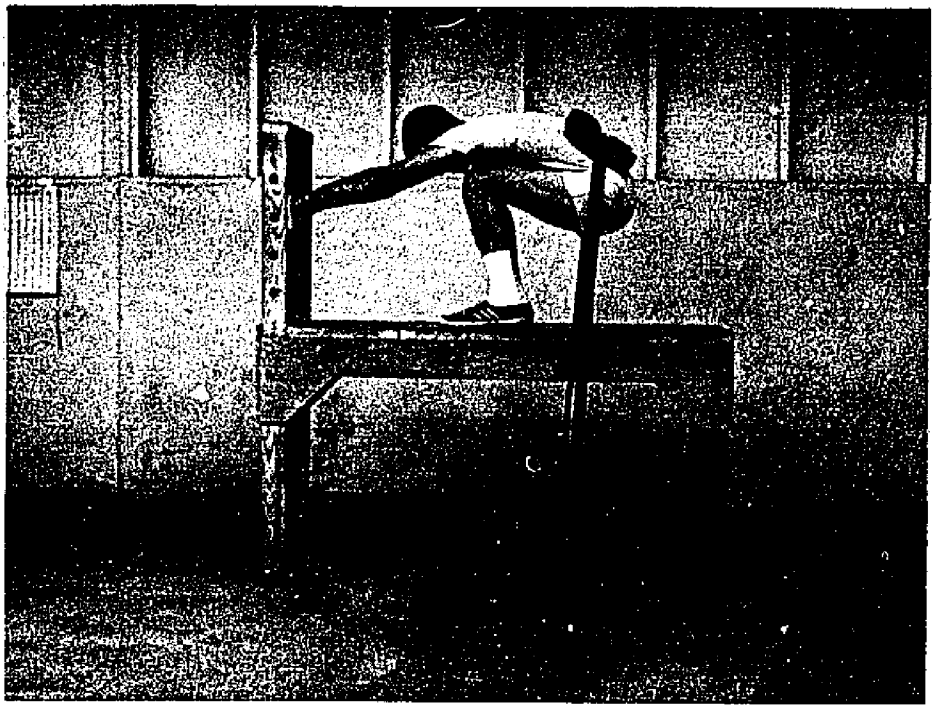
FIGURE 2

ISOMETRIC TESTING PROCEDURE

lifted one time (1-RM) from a beginning angle of 90° of the leg on the thigh to the lockout position (180°). Group IV was retested on the day following the initial test to determine the reliability of the testing procedure. The equipment used was three exercise tables, three pre-stretched nylon web belts, three back pads, three weight suspension bars, 1200 pounds of plate weights and three goniometers. Three assistant testers, one at each of three testing stations, aided in the administration of the tests.

The angle of the leg on the thigh was determined as in the isometric test. (See Figure 1, page 42.) Once the adjustment for the belt loop was determined, further measurements were unnecessary. The subject assumed a standing position upon the table with the back parallel to the floor. With the weight resting on the floor, the belt loop was determined which allowed a maximum 90° angle of the knee just as the weight touched the floor. To complete an acceptable repetition, the subject was required to lift the weight from the floor, through the range of motion to the lockout position at a 180° angle and then return the weight to the floor. Before a second repetition was initiated the weight was required to touch the floor, but only momentarily, and then the lift was again attempted to the lockout position. Figure 3 illustrates the isotonic testing procedure.

The position of the subject was nearly identical to that of the isometric test except the hands grasped the "steady bar" in front of the individual. The belt was positioned over the lower three



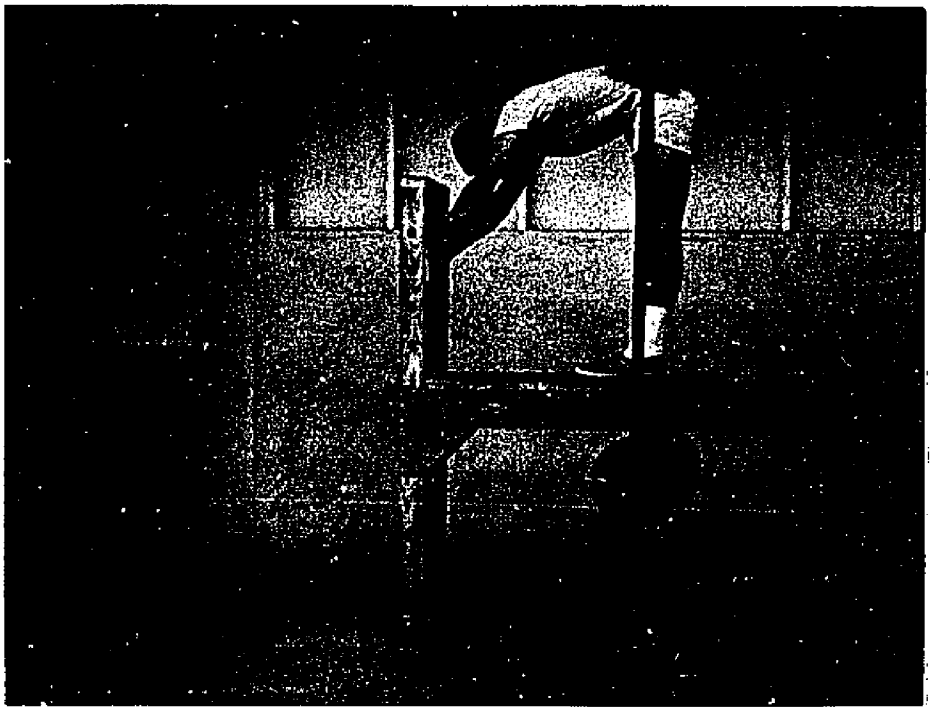


FIGURE 3

ISOTONIC TESTING PROCEDURE

lumbar vertebrae. The subject was instructed to keep the heels flat on the table at all times and the assistant tester steadied the weight and the subject if needed.

The approximate 1-RM was found during the last day of the familiarity procedure. With this as a guide, ten pound increments were added until the 1-RM was found. A minimum two minute rest period was taken between lifts.[1] The resistance thus lifted was recorded as the maximum isotonic score for the individual.

Vertical Jump

All subjects were tested initially and finally using a modified vertical jump test. A group outside of the proposed study was tested and retested to determine the reliability of the testing procedure. The apparatus used was a belt, closed face spinning reel, and other miscellaneous items, shown in Figure 4 which presents a photograph of the vertical jump testing apparatus.

Attached to the side center of the belt was a hook to which the measuring apparatus was attached. The measuring device consisted of an ordinary closed face spinning reel with pre-stretched line. The reel was attached to one end of a five foot long, one inch by four inch board. Eyescrews were inserted into the board near the reel and at the opposite end of the board. Between the eyescrews,

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[1] Richard A. Berger, "Comparison of the Effect of Various Weight Training Loads on Strength," Research Quarterly, XXXVI (1965), 142.

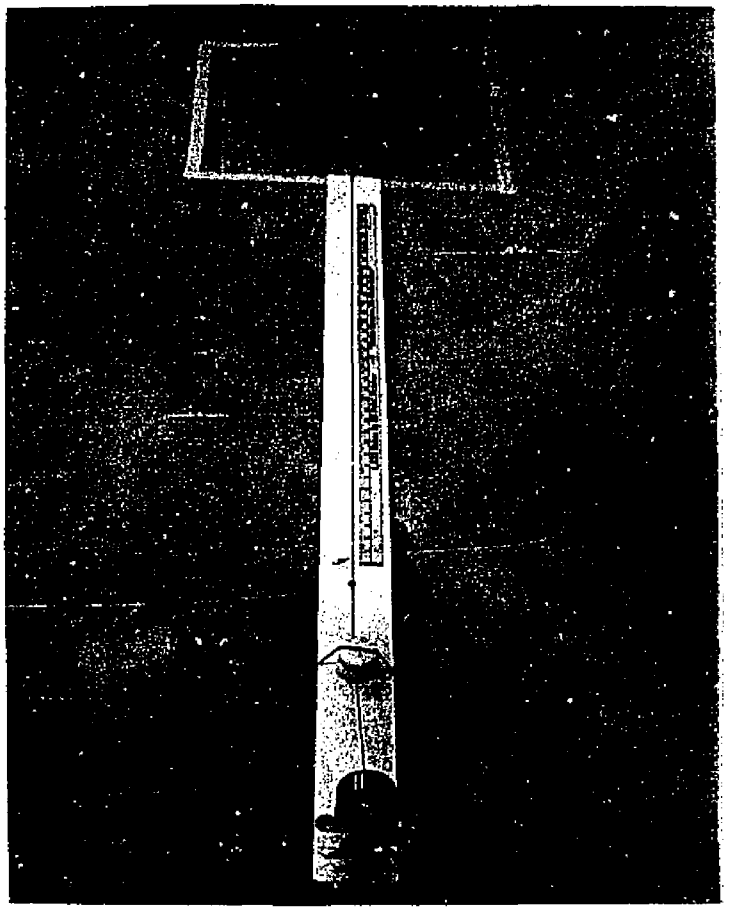

FIGURE 4

VERTICAL JUMP TESTING APPARATUS

the board was marked off in $\frac{1}{4}$-inch segments for a distance of three feet. The line from the reel was placed through the eyescrews and attached to the hook of the belt. A spring clip was attached to the line at the zero mark on the board before each jump. The board was solidly attached to the floor. On the floor at the end of the board a twenty inch square was marked off within which the subject was required to initiate the jump.

The belt was snugly positioned at the iliac crests and the line attached to the hook on the belt. The subject grasped his shorts and held them throughout the jump. The back was held as straight as possible (consistent with balance) on the knee flexion movement. The subject then executed the jump and the distance jumped was the distance the clip on the line had moved along the board. To be considered a good jump, the subject was required to land in the twenty inch square. The best of three jumps was recorded as the vertical jump score. Figure 5 presents photographs of the vertical jump testing procedure.

IV. TRAINING PROCEDURE

The training period was seven weeks in length. Group V served as the control group and received no training other than participation in their regularly scheduled physical education classes and the familiarity routines.

FIGURE 5

VERTICAL JUMP TESTING PROCEDURE

Isometric

Groups I, II, and III trained at their respective angles of 95°, 125°, and 155° and participated in their scheduled physical education classes. The same equipment and technique that were used in isometric testing were utilized in the training program. Each subject performed a single ten second maximum contraction at the designated angle, three days a week. Weekly scores were recorded on the last day of the training week for motivational purposes.

Isotonic

Group IV trained in the isotonic hip press using the same apparatus that was used in the isotonic testing as well as participated in their scheduled physical education classes. The 4-RM, which has been found to be approximately 92.4 per cent of the 1-RM,[2] was the training weight. Each subject did as many repetitions as possible in a ten second period with the 4-RM. A new 1-RM was determined each Friday and from Berger's[3] chart, the 4-RM was calculated for training the following week.

The subject mounted the bench, and the belt was adjusted to the predetermined loop. The proper 4-RM was loaded. The subject was positioned properly and began the repetitions. When the subject

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[2]Richard A. Berger, "Determination of the Resistance Load for 1-RM and 10-RM," Journal of the Association for Physical and Mental Rehabilitation, XV (1961), 110.

[3]Ibid.

could perform no more repetitions or the ten second period had elapsed, the weight was lowered to the floor.

V. TREATMENT OF DATA

The reliability of the testing procedures was determined by use of the Pearson-Product-Moment method of correlation on the initial test and retest scores.

The significance of the difference between initial and final scores of each group on each test was computed and the t-ratio applied to determine the significance of the gains within groups.

The analysis of covariance technique was utilized to determine the significance of the difference between groups on each testing situation. When a significant F was found in any of the covariance analyses, the orthogonal comparison technique was utilized to determine the treatment or combination of treatments responsible for the significant differences found.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

I. INTRODUCTION

The basic data analyzed in the study were the initial and final test scores recorded on three isometric tests at 95°, 125°, and 155° angles of the leg on the thigh, an isotonic test through the same approximate range of motion and a vertical jump test. Retest scores ascertained on each of the five tests were also utilized. The raw data are presented in Appendixes A through E.

The statistical techniques applied in the study were: (1) the Pearson-Product-Moment method of correlation on initial and retest scores to determine the reliability of the testing techniques; (2) the application of the t test to determine the significance of the difference between correlated means; and (3) analysis of covariance with orthogonal comparisons.

II. ANALYSIS OF TEST RELIABILITY

A retest was given to the group exercising in the specific isometric and isotonic testing technique and a separate group outside of the study was tested initially and retested in the vertical jumping technique. The initial test and retest scores for each test were analyzed by the Pearson-Product-Moment method and coefficients of

correlation computed. The correlations ranged from a high of .97 to a low of .92, and all tests were deemed reliable for the purpose of the study. Correlation coefficients are presented in Table I.

TABLE I

RELIABILITY COEFFICIENTS FOR INITIAL TEST AND RETEST IN THREE ISOMETRIC STRENGTH TEST POSITIONS, AN ISOTONIC STRENGTH TEST AND A VERTICAL JUMP TEST

	Initial Test	Retest	r
95° Isometric Mean Score N=24	106.04*	105.41	.94
125° Isometric Mean Score N=24	344.38*	346.67	.92
155° Isometric Mean Score N=24	821.04*	823.13	.97
Isotonic Mean Score N=24	163.67*	166.67	.97
Vertical Jump Mean Score N=24	19.38**	19.57	.95

* Pounds
** Inches

III. THE SIGNIFICANCE OF THE MEAN GAIN OF EACH GROUP ON ISOMETRIC, ISOTONIC AND VERTICAL JUMP TESTS

The significance of the mean difference between initial and final tests within the individual groups on each of the five tests

was established by application of the t-ratio. To reach significance at the .01 level of probability for 23 (24-1) degrees of freedom, a t-ratio of 2.81 was required and a t-ratio of 2.07 was required at the .05 level. Each analysis is presented individually by testing technique.

95° Isometric Strength Test

A t-ratio of 2.92 was found when the initial and final mean strength test scores at 95° were compared for Group I which exercised at 95°. Table II indicates that this t was significant at the .01 level of probability and therefore the mean gain of 8.96 pounds from initial to final tests was significant, thus indicating that isometric exercise in the 95° position did increase strength at that same position.

The only other group to show a significant gain at this position was Group IV, the subjects who exercised isotonically. A mean gain of 6.25 pounds yielded a t-ratio of 2.11, which was significant at the .05 level of probability. Therefore, an isotonic exercise routine as utilized in this study did significantly increase isometric strength at a 95° angle of the leg on the thigh. (See Table II.)

Group II which exercised isometrically at 125° showed a mean gain of 1.25 pounds and a t-ratio of .46, which was not significant. Isometric strength at 95° was not significantly increased when an isometric exercise was performed at 125°. (See Table II.)

TABLE II

SIGNIFICANCE OF MEAN DIFFERENCE BETWEEN INITIAL AND FINAL TEST SCORES AT 95° KNEE EXTENSION FOR GROUPS I, II, III, IV AND V (N=24)

Group	Mean	Mean Diff.	$\sigma_{Diff.}$	t	P
I (95°)					
Initial	106.04				
		8.96	3.07	2.92	.01
Final	115.00				
II (125°)					
Initial	104.79				
		1.25	2.71	.46	NS
Final	106.04				
III (155°)					
Initial	105.21				
		-4.38	2.92	1.50	NS
Final	100.83				
IV (Isotonic)					
Initial	94.17				
		6.25	2.97	2.11	.05
Final	100.42				
V (Control)					
Initial	105.21				
		-8.96	3.46	2.59	.05
Final	96.25				

Groups III (exercised at 155°) and V (control) were found to have negative mean gains of 4.38 pounds and 8.96 pounds, respectively. A t-ratio of 1.50 was computed for Group III and was not significant but the t of 2.59 for Group V was significant at the .05 level of probability. Whereas Group III indicated that exercise at 155° did not significantly increase strength measured at 95°, the results from Group V showed a significant decrease in strength at 95°. It was hypothesized that this result was due to the uniqueness and difficulty of the testing procedure combined with the lack of motivation in the final testing situation. (See Table II, page 56.)

125° Isometric Test

From Table III it can be seen that a significant t-ratio was found for all groups on the 125° isometric test. Groups I (trained at 95°), II (trained at 125°), III (trained at 155°), and Group IV (trained isotonically) reflected mean gains of 87.08 pounds, 125.83 pounds, 111.04 pounds, and 116.04 pounds, respectively. These mean gains resulted in t-ratios significant at the .01 level of probability of 4.23, 8.19, 5.28, and 7.42, respectively. Therefore, isometric exercise at 95°, 125°, 155°, and isotonic exercise will significantly increase strength at 125° as determined by this study.

Group V yielded a mean gain of 45.42 pounds and a t-ratio of 2.12 which was barely significant at the .05 level of probability. Although significant, the large difference between the gain for

TABLE III

SIGNIFICANCE OF MEAN DIFFERENCE BETWEEN INITIAL AND FINAL TEST SCORES AT 125° KNEE EXTENSION FOR GROUPS I, II, III, IV AND V (N=24)

Group	Mean	Mean Diff.	σ Diff.	t	P
I (95°)					
Initial	328.54				
		87.08	20.57	4.23	.01
Final	415.62				
II (125°)					
Initial	344.38				
		125.83	15.36	8.19	.01
Final	470.21				
III (155°)					
Initial	322.71				
		111.04	21.04	5.28	.01
Final	433.75				
IV (Isotonic)					
Initial	281.67				
		116.04	15.64	7.42	.01
Final	397.71				
V (Control)					
Initial -	308.13				
		45.42	21.40	2.12	.05
Final	353.55				

Group V and all other groups should be noted, and it is also pointed out that the largest gain was at the 125° position of exercise. (See Table III, page 58.)

155° Isometric Test

Table IV reflects the fact that all groups on the 155° isometric test were found to have a significant t-ratio at the .01 level of probability. Mean gains of 234.38 pounds, 283.13 pounds, 270.21 pounds, 247.29 pounds and 198.33 pounds and t-ratios of 5.44, 5.51, 7.27, 6.30 and 4.90 were found for Groups I (95°), II (125°), III (155°), IV (isotonic) and V (control), respectively.

Again it should be pointed out that the control group (Group V) achieved the smallest mean gain by 36.05 pounds.

Isotonic Test

All groups made significant gains at the .01 level of probability on the isotonic test. Group I (95°) had a mean gain of 25.83 pounds and a t-ratio of 6.71; Group II (125°) had a mean gain of 32.08 pounds and a t-ratio of 7.12; Group III (155°) had a mean gain of 20.42 pounds and a t-ratio of 6.47; Group IV (isotonic) had a mean gain of 56.25 pounds and a t-ratio of 10.15; and Group V (control) had a mean gain of 21.25 pounds and a t-ratio of 3.42. (See Table V, page 61.)

Vertical Jump Test

It is indicated in Table VI, page 62) that Group II (125°)

TABLE IV

SIGNIFICANCE OF MEAN DIFFERENCE BETWEEN INITIAL AND FINAL TEST SCORES AT 155° KNEE EXTENSION FOR GROUPS I, II, III, IV AND V (N=24)

Group	Mean	Mean Diff.	σ Diff.	t	P
I (95°)					
Initial	771.67				
		234.38	43.05	5.44	.01
Final	1006.05				
II (125°)					
Initial	777.50				
		283.13	51.37	5.51	.01
Final	1060.63				
III (155°)					
Initial	821.04				
		270.21	37.19	7.27	.01
Final	1091.25				
IV (Isotonic)					
Initial	798.33				
		247.29	39.24	6.30	.01
Final	1045.62				
V (Control)					
Initial	834.17				
		198.33	40.48	4.90	.01
Final	1032.50				

TABLE V

SIGNIFICANCE OF MEAN DIFFERENCE BETWEEN INITIAL AND FINAL TEST SCORES ON THE ISOTONIC TEST FOR GROUPS I, II, III, IV AND V (N=24)

Group	Mean	Mean Diff.	$\sigma_{Diff.}$	t	P
I (95°)					
Initial	166.17				
		25.83	3.85	6.71	.01
Final	192.00				
II (125°)					
Initial	168.67				
		32.08	4.50	7.12	.01
Final	200.75				
III (155°)					
Initial	167.83				
		20.42	3.16	6.47	.01
Final	188.25				
IV (Isotonic)					
Initial	163.67				
		56.25	5.54	10.15	.01
Final	219.92				
V (Control)					
Initial	158.67				
		21.25	6.21	3.42	.01
Final	179.92				

TABLE VI

SIGNIFICANCE OF MEAN DIFFERENCE BETWEEN INITIAL AND FINAL TEST SCORES ON THE VERTICAL JUMP TEST FOR GROUPS I, II, III, IV AND V (N=24)

Group	Mean	Mean Diff.	$\sigma_{Diff.}$	t	P
I (95°)					
Initial	17.90				
		.53	.20	2.66	.05
Final	18.43				
II (125°)					
Initial	17.56				
		.90	.26	3.46	.01
Final	18.46				
III (155°)					
Initial	17.60				
		.53	.35	2.15	.05
Final	18.13				
IV (Isotonic)					
Initial	17.86				
		.42	.20	2.12	.05
Final	18.28				
V (Control)					
Initial	18.22				
		.29	.25	1.16	NS
Final	18.51				

had a mean gain of .90 inches and a t-ratio of 3.46 which was significant at the .01 level of probability. Groups I (95°), III (155°), and IV (isotonic) achieved mean gains of .53 inches, .53 inches, and .42 inches and t-ratios of 2.66, 2.15 and 2.12, respectively. All were significant at the .05 level of probability. The above stated facts indicated that all of the three isometric exercises and the isotonic exercise brought about significant improvement in vertical jumping ability as measured by the methods of this study.

Group V, the control group, recorded a mean gain of .29 inches and a t-ratio of 1.16 which was not significant, thus indicating that no exercise apart from the regular physical education class activities resulted in no changes in vertical jumping performance. (See Table VI, page 62.)

IV. ANALYSIS OF COVARIANCE

Analysis of covariance was utilized to determine if significant differences existed among the five groups in each of the testing situations. The analysis of covariance technique is an extension of analysis of variance with the synthesis of regression. Covariance provides increased precision of the error estimate through reduction of chance error by equalizing initial individual differences with respect to the criterion trait. Adjustment of the final scores is made by determination of the regression of final criterion traits on the initial criterion traits. For 4 and 114

degrees of freedom, an F of 2.45 at the .05 level of probability and 3.49 at the .01 level were necessary to indicate that significant differences existed among the groups.

Significant F-ratios of 5.81, 3.81 and 9.96 were found for the 95° isometric test, 125° isometric test and the isotonic test, respectively. (See Tables VII, VIII and IX.)

TABLE VII

ANALYSIS OF COVARIANCE OF ISOMETRIC STRENGTH SCORES AT 95° KNEE EXTENSION FOR SUBJECTS IN THE ISOMETRIC (95°, 125°, 155°), ISOTONIC AND CONTROL GROUPS

Source of Variance	Sum of Squares	df	Mean Squares	F	P
Among	4,956	4	1,239	5.81	.01
Within	24,322	114	213		
Total	29,278	118			

F needed at .05 level, 2.45; at .01 level, 3.49

TABLE VIII

ANALYSIS OF COVARIANCE OF ISOMETRIC STRENGTH SCORES AT 125° KNEE EXTENSION FOR SUBJECTS IN THE ISOMETRIC (95°, 125°, 155°), ISOTONIC AND CONTROL GROUPS

Source of Variance	Sum of Squares	df	Mean Squares	F	P
Among	117,396	4	29,349	3.81	.01
Within	877,809	114	7,700		
Total	995,205	118			

F needed at .05 level, 2.45; at .01 level, 3.49

However, Tables X and XI also reflect the fact that the F-ratios of .53 for the 155° isometric test and .79 for the vertical jump test were not significant. When an F is found to be non-significant there is ordinarily no reason for further testing, since none of the means will likely be found significantly different from any other mean.[1] However, a significant F indicates that at least one of the mean differences is reliably different from some others and orthogonal comparison was the method utilized in this study to determine exactly where those differences were located.

TABLE IX

ANALYSIS OF COVARIANCE OF ISOTONIC STRENGTH SCORES FOR SUBJECTS IN THE ISOMETRIC (95°, 125°, 155°), ISOTONIC AND CONTROL GROUPS

Source of Variance	Sum of Squares	df	Mean Squares	F	P
Among	20,943	4	5,236	9.96	.01
Within	60,264	114	529		
Total	81,206	118			

F needed at .05 level, 2.45; at .01 level, 3.49

Although non-significant F-ratios were found on the 155° isometric test and the vertical jump test, there is information to be gleaned from the statistical analysis. All groups in the 155° isometric

[1]Henry E. Garrett, Statistics in Psychology and Education (New York: David McKay Company, Inc., 1958), p.284.

TABLE X

ANALYSIS OF COVARIANCE OF ISOMETRIC STRENGTH SCORES AT 155° KNEE EXTENSION FOR SUBJECTS IN THE ISOMETRIC (95°, 125°, 155°), ISOTONIC AND CONTROL GROUPS

Source of Variance	Sum of Squares	df	Mean Squares	F	P
Among	88,751	4	22,188	.53	NS
Within	4,743,065	114	41,606		
Total	4,831,816	118			

F needed at .05 level, 2.45; at .01 level, 3.49

TABLE XI

ANALYSIS OF COVARIANCE OF VERTICAL JUMP SCORES FOR SUBJECTS IN THE ISOMETRIC (95°, 125°, 155°), ISOTONIC AND CONTROL GROUPS

Source of Variance	Sum of Squares	df	Mean Squares	F	P
Among	3.98	4	.99	.79	NS
Within	143.35	114	1.26		
Total	147.33	118			

F needed at .05 level, 2.45; at .01 level, 3.49

test did exhibit significant gains from initial to final tests. Coupled with the information from the analysis of covariance, this indicated that the three isometric and the isotonic training routines brought about significant gains in isometric strength at 155° but that any one training routine was just as good as any other.

The explanation as to why there was not a significant difference in the gains of the control group (Group V) when contrasted to the training groups is apparent even though the mean gain of Group V is clearly less by some 36 pounds. It is likely that the gains among the individual groups were so small that significant differences were not found.

The F-ratio of .79 on the covariance analysis of the vertical jump test scores was also non-significant, but this was not entirely unexpected after reviewing the literature on vertical jump testing.

The three isometric training groups and the isotonic training group showed significant gains in vertical jumping ability whereas the control group did not. Coupled with the insignificant F-ratio on covariance analysis, this indicated that any of the training methods brought about significant gains in vertical jumping ability but that no one training method was any better than any other method. The control group did not show significant gains. It is likely that any significant difference in performance of this group and that of the other groups was masked by the small differences found among the groups.

Orthogonal Comparisons on 95° Isometric Test

The significant F of 5.81 yielded by covariance analysis of the five groups on the 95° isometric test warranted the use of orthogonal comparisons to identify the significant differences. There were K-1 comparisons, or in this case 4 (5-1), comparisons available. In order to be significant, an F-ratio of 3.93 at the .05 level of probability and 6.87 at the .01 level was needed for 1 and 114 degrees of freedom. The following orthogonal design was used in the 95° isometric testing situation:

	95° Isometric Group I	125° Isometric Group II	155° Isometric Group III	Isotonic Group IV	Control Group V
Adjusted Final Mean	112.4	104.5	98.9	108.3	94.4
Comparison I	0	+1	-1	0	0
Comparison II	+2	-1	-1	0	0
Comparison III	+1	+1	+1	-3	0
Comparison IV	+1	+1	+1	+1	-4

The first comparison composed of the 125° isometric training group versus the 155° isometric training group was found to have a sum of squares of 374 which yielded a nonsignificant F-ratio of 1.75. Therefore, there was not a significant difference between the effects of training isometrically at 125° and 155° on isometric strength at a 95° angle of the leg on the thigh. (See Table XII.)

Comparison II, in which Group I trained at 95°, was contrasted with a combination of Group II (125°) and Group III (155°)

yielded a sum of squares of 1,749 and a subsequent F of 8.21 which was significant at the .01 level of probability. Thus, there was a significant difference between training at 95° and a combination of training at 125° and 155° and since comparison I yielded a non-significant difference between training at 125° and 155° it can be inferred that training at 95° was significantly better than training at either 125° or 155° in bringing about a strength increase at 95°. This was to be expected since a comparison of initial and final scores of Group I yielded a significant t-ratio while a similar comparison on Groups II and III did not. (See Table XII.)

TABLE XII

ORTHOGONAL COMPARISONS OF ISOMETRIC STRENGTH SCORES AT 95° KNEE EXTENSION FOR SUBJECTS IN THE ISOMETRIC (95°, 125°, 155°), ISOTONIC AND CONTROL GROUPS

Comparison	Sum of Squares	df	Mean Squares	F	P
125° vs 155°	374	1	374	1.75	NS
95° vs 125° & 155°	1,749	1	1,749	8.21	.01
Isometric vs Isotonic	162	1	162	.76	NS
Training vs Control	2,614	1	2,614	12.27	.01
ERROR	24,322	114	213		

F needed at .05 level, 3.93; at .01 level, 6.87

The third comparison contrasted the three isometric groups (I, II, and III) to the isotonic group (Group IV). The sum of

squares of 162 resulted in an F-ratio of .76 which was not significant. There was not a significant difference, therefore, between the combination of three isometric exercises at 95°, 125°, and 155° and the isotonic routine. However, Group IV did show a significant gain from initial to final tests, and it was possible that by combining Group I with Groups II and III there was a masking of actual differences between Group IV and either Group II or Group III. These comparisons could not be made and still meet the requirements of orthogonality.

In comparing Groups I, II, III, and IV to Group V, the control group (comparison IV), a sum of squares of 2,614 yielded an F of 12.27 which was significant at the .01 level, thus indicating that a significant difference existed between a combination of the three isometric and the isotonic routines when contrasted to the control group which participated only in the physical education classes.

It was evident then that isometric exercise at 95° was significantly superior to isometric exercise at either 125° or 155° when desiring to increase strength at 95° and that a combination of three isometric exercises at 95°, 125°, and 155° was not significantly superior or inferior to an isotonic training routine as used in this study in developing strength at 95°.

Orthogonal Comparisons on 125° Isometric Test

Covariance analysis of the five groups on the 125° isometric test yielded an F of 3.81 which was significant at the .01 level.

The following orthogonal design was then employed to determine the groups among which the differences existed.

	95° Isometric Group I	125° Isometric Group II	155° Isometric Group III	Isotonic Group IV	Control Group V
Adjusted Final Mean	408.7	453.6	430.4	418.7	358.8
Comparison I	+1	0	-1	0	0
Comparison II	-1	+2	-1	0	0
Comparison III	+1	+1	+1	-3	0
Comparison IV	+1	+1	+1	+1	-4

The first comparison between the group that exercised at 95° and the group that exercised at 155° yielded a sum of squares of 5,592.2 and an F-ratio of .71 which was not significant. Therefore, although both groups exhibited significant gains from initial to final tests, there was not a significant difference between the two groups in terms of strength developed at a 125° angle of the leg on the thigh. (See Table XIII.)

Comparison II between the group training at 125° and a combination of the groups training at 95° and 155° found a sum of squares of 18,756.7 and an F of 2.43 which was not significant. It is evident that training at 125° had no significant merit over training in a combination of 95° and 155° when strength development at 125° was the goal. Since Group II did exhibit significant gains from initial to final tests, it can be inferred that any single isometric training method used in this study was as good as any

other isometric training routine in developing strength at 125°. (See Table XIII.)

TABLE XIII

ORTHOGONAL COMPARISONS OF ISOMETRIC STRENGTH SCORES AT 125° KNEE EXTENSION FOR SUBJECTS IN THE ISOMETRIC (95°, 125°, 155°), ISOTONIC AND CONTROL GROUPS

Comparison	Sum of Squares	df	Mean Squares	F	P
95° vs 155°	5,592.2	1	5,592.2	.71	NS
125° vs 95° & 155°	18,756.7	1	18,756.7	2.43	NS
Isometric vs Isotonic	2,561.6	1	2,561.6	.33	NS
Training vs Control	91,431.2	1	91,431.2	11.87	.01
ERROR	877,809.6	114	7,700.1		

F needed at .05 level, 3.93; at .01 level, 6.87

The third comparison contrasted the three isometric training groups to the isotonic group. This comparison yielded a sum of squares of 2,561.6 and an F of .33 which was not significant. Thus, an isotonic training routine as utilized in this study was as effective in developing isometric strength at 125° as a combination of the three isometric training procedures and further, since there was no significant difference among the three isometric routines, any single isometric routine was as effective as the isotonic routine.

Comparison IV was between the control group (Group V) and a combination of Groups I, II, III, and IV. A sum of squares of

91,431.2 was found and resulted in an F of 11.87 which was significant at the .01 level of probability. Therefore, a combination of three isometric and an isotonic training routine was significantly superior to participation in a physical education activity class in developing strength at 125°. Since there were no significant differences found among the training routines of Groups I, II, III, and IV, it can be stated that any single training routine was significantly superior to participation in a physical education activity class alone.

Orthogonal Comparisons on Isotonic Test

The analysis of covariance technique applied to the five groups on the isotonic test resulted in an F of 9.96 which was significant at the .01 level of probability and indicated that significant differences existed among the groups. The following orthogonal design was used to determine where the differences existed.

	95° Isometric Group I	125° Isometric Group II	155° Isometric Group III	Isotonic Group IV	Control Group V
Adjusted Final Mean	191.0	197.6	185.8	221.0	185.3
Comparison I	+1	-1	0	0	0
Comparison II	+1	+1	-2	0	0
Comparison III	+1	+1	+1	-3	0
Comparison IV	+1	+1	+1	+1	-4

Table XIV reflects that in comparison I between the group training at 95° and the group training at 125° a sum of squares of 525.7 was found. This resulted in an F-ratio of .99 which was not significant. Thus, there was no significant difference between isometric exercise at 95° and 125° in developing isotonic strength as measured in this study. However, both training methods brought about significant gains in isotonic strength.

TABLE XIV

ORTHOGONAL COMPARISONS OF ISOTONIC STRENGTH SCORES FOR SUBJECTS IN THE ISOMETRIC (95°, 125°, 155°), ISOTONIC AND CONTROL GROUPS

Comparison	Sum of Squares	df	Mean Squares	F	P
95° vs 125°	525.7	1	525.7	.99	NS
155° vs 95° & 125°	1,150.6	1	1,150.6	2.17	NS
Isometric vs Isotonic	15,696.6	1	15,696.6	29.69	.01
Training vs Control	3,502.8	1	3,502.8	6.62	.05
ERROR	60,263.9	114	528.6		

F needed at .05 level, 3.93; at .01 level, 6.87

The second comparison contrasted Groups I (95°) and II (125°) to Group III (155°) and yielded a sum of squares of 1,150.6 and a resultant F of 2.17 which was not significant. It can be seen that there was no significant benefit in using one isometric exercise

over any other isometric exercise in developing isotonic strength and that any one of the three brought about significant gains.

In the third comparison the three isometric groups (Groups I, II, and III) were contrasted to Group IV, the isotonic training group. This resulted in a sum of squares of 15,696.6 and an F of 29.69 which was significant at the .01 level of probability. It is clearly evident that isotonic exercise was significantly superior to a combination of the three isometric training training routines and likely that it was superior to any one singly in the development of isotonic strength. That is to say that although the isometric training routines resulted in significant isotonic strength gains, the isotonic training routine brought about a significantly greater improvement in isotonic strength than the isometric routines.

Comparison IV was between Groups I, II, III, and IV in combination and Group V, the control group. An F of 6.62, significant at the .05 level of probability, resulted from a sum of squares of 3,502.8.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, RECOMMENDATIONS

I. SUMMARY

It was the purpose of this study to: (a) compare the effects of an isotonic knee extension exercise on isometric knee extensor strength at angles of 95°, 125°, and 155°, isotonic strength in the same range of motion and vertical jumping ability; and (b) compare the effects of an isometric knee extension exercise at 95°, 125°, and 155° on isometric strength at those same angles, isotonic strength in the same range of motion and vertical jumping ability.

The subjects of the study were 120 male undergraduate students enrolled at Central Missouri State College during the summer of 1966. All subjects participated in a one week familiarity routine in which they experienced all testing and training methods. After the familiarity routine, all subjects were tested on isometric knee extensor strength tests at 95°, 125°, and 155° angles of the leg on the thigh, on an isotonic knee extensor strength test through a similar range of motion (90° through 180°) and on a vertical jump test. The subjects were then randomly divided into five training groups of twenty-four each: Group I trained isometrically at a 95° angle of the knee; Group II trained isometrically at a 125° angle of the knee; Group III trained isometrically at a 155° angle of the

knee; Group IV trained isotonically; and Group V served as a control group receiving no training other than participation in the same physical education activity classes as all other subjects. All of the 120 subjects were enrolled in one of the following physical education activity classes: archery, badminton, tennis, volleyball, or introduction to physical activity.

In order to determine the reliability of the tests, Groups I, II, III, and IV were retested the period following the initial test in their testing technique. A separate group outside of the study was tested initially and retested on the vertical jump test. All tests were found reliable as shown in Table I, page 54.

The subjects then underwent a seven week training program in which they met three days a week. Groups I, II, and III performed a single ten-second isometric contraction at the assigned position of exercise each training day. Group IV performed an isotonic hip press exercise with the 4-RM weight for ten seconds. Group V only attended their regularly assigned activity class.

During the seventh training week all subjects repeated the familiarity program and during the following week all subjects were given the final test in all five testing situations.

The t test was applied to determine the significance of the difference between initial and final test means for each group on each test. Covariance analysis was then computed for the groups on each test to compare the effectiveness of the training methods on improvement in the criterion traits. When significant F-ratios were

found, orthogonal comparisons were utilized to determine where the significant differences existed among the groups on the criterion trait.

II. FINDINGS

The findings revealed by this study were as follows:

1. Isometric exercise at a 95° angle of knee extension did significantly increase isometric strength at 95°, 125°, and 155° angles of knee extension and also significantly increased isotonic knee extensor strength and vertical jumping ability.
2. Isometric exercise at a 125° angle of knee extension did significantly increase isometric strength at 125° and 155° angles of knee extension and also significantly increased isotonic knee extensor strength and vertical jumping ability but did not significantly increase isometric strength at 95°.
3. Isometric exercise at a 155° angle of knee extension did significantly increase isometric strength at 125° and 155° angles of knee extension and also significantly increased isotonic knee extensor strength and vertical jumping ability but resulted in no gain at 95°.
4. Isotonic exercise in a 90° through 180° knee extension range of motion did significantly increase isotonic knee extensor strength, vertical jumping ability and isometric

knee extensor strength at angles of 95°, 125°, and 155°.

5. The control group exhibited a significant loss in isometric knee extensor strength at 95°, a significant gain in 125° and 155° isometric knee extensor strength and isotonic knee extensor strength and no significant change in vertical jumping ability.
6. Comparison of the five groups in the study on the isometric strength test at 155° revealed that no significant differences occurred among the three isometric training routines, the isotonic training and the control group.
7. There were no significant differences found among the three isometric training routines, the isotonic training and the control group on the vertical jump test.
8. A significant difference was found among the five training groups in the comparison on the 95° isometric test and orthogonal comparisons further revealed:
   a. No significant difference between Group II (125°) and Group III (155°).
   b. A significant difference between Groups II (125°) and III (155°) combined and Group I (95°) in favor of Group I.
   c. No significant difference between Groups I (95°), II (125°) and III (155°) combined and Group IV (isotonic).
   d. A significant difference between Groups I (95°), II (125°), III (155°) and IV (isotonic) combined and

Group V (control) in favor of the combined groups.

9. A comparison of the five training groups on the 125° isometric strength test revealed that significant differences existed among the groups and orthogonal comparisons revealed:
   a. No significant difference between Group I (95°) and Group III (155°).
   b. No significant difference between Groups I (95°) and III (155°) combined and Group II (125°).
   c. No significant difference between Groups I (95°), II (125°) and III (155°) combined and Group IV (isotonic).
   d. A significant difference between Groups I (95°), II (125°), III (155°) and IV (isotonic) combined and Group V in favor of the combined groups.
10. When the five training groups were compared on the isotonic strength test, significant differences were found to exist among the groups and orthogonal comparisons revealed:
   a. No significant difference between Group I (95°) and Group II (125°).
   b. No significant difference between Groups I (95°) and II (125°) combined and Group III (155°).
   c. A significant difference between the three isometric training groups (Groups I, II, and III) and Group IV (isotonic) in favor of Group IV.
   d. A significant difference between the four training

groups (Groups I, II, III, and IV) and Group V (control) in favor of the combined groups.

11. Coefficients of correlation computed on two test scores acquired on different occasions for the five testing techniques revealed that the tests were reliable.

III. DISCUSSION

A few significant facts should be brought to the attention of the reader at this point. Concerning the significance of the mean gain of each group on the various tests, it should be pointed out that although the control group (Group V) made significant gains on the 125° and 155° isometric tests and the isotonic test, this was probably due to the participation in regularly scheduled physical education activity classes and was not entirely unexpected. The more logical question would be why the control group in the 95° isometric test did not achieve significant gains. This might be explained by the proposed phenomenon called position specificity of strength gains, provided it exists, since seldom in the activities participated in by the subjects was force exerted from an angle of 95° of the leg on the thigh. However, force was often exerted by these muscle groups at angles of 125° and 155° which are nearer the end of the range of motion.

Perhaps one question which confronts the reader would be why the training groups (Groups I, II, III, and IV) did not achieve significant gains when compared to the control group in the 155°

isometric strength test and the vertical jump test. The insignificant F on covariance analyses of these two testing situations revealed this to be a fact. The most likely explanation would be that the mean gains of the control group in each situation were sufficient to negate significant differences. However, combined with the small differences found among the four training groups which masked the difference between the four groups and the control group, it is obvious by inspection of the mean gains that there was considerably more improvement by the four training groups than by the control group in both instances.

In addition, it is clearly evident that in the three testing situations which yielded significant F-ratios on covariance analysis, the group that exercised in the testing method showed the greatest gains. The 95° isometric training method group exhibited significantly greater gains than did the other two isometric training methods on the 95° isometric test but could not be compared to the isotonic training group individually and still retain orthogonality in the comparison. It was found that the isotonic training group made significantly greater gains than did any of the isometric training groups on the isotonic test.

The 125° isometric training group exhibited the greatest gains on the 125° isometric test but these gains were not significantly greater than those of any other training group in the comparisons chosen. Although the above statements suggest the possibility of a position specificity of strength gains, the overall

findings of the study tend to substantiate an earlier study by the author[1] which found that the knee extensor muscles have a low position specificity of strength gains.

It might also be pointed out that the familiarity routine was utilized to negate the effects of learning on gains achieved on the final test. It was hypothesized that significant gains are sometimes achieved in studies simply because the technique of taking the test was "learned" after having the initial test.[2] It was hoped that a familiarity routine might also keep to a minimum those quick gains often achieved in the first week or two of many training programs. A scan of the weekly strength scores indicated that this was achieved.

Another definitive aspect of this particular study was that the isotonic group exercised for the identical length of time as the isometric groups. The fact that isotonic exercise was as effective in developing isometric strength at the 125° and 155° positions coupled with the findings of Rasch and Pierson[3] which revealed isometric testing techniques as valid in expressing isotonic strength

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[1]Duane R. Sterling, "A Comparative Study of the Specificity in Position Selectivity of Isometric Strength Changes in the Knee Flexor Muscle Group Resulting From Isometric Exercise: A Restudy (unpublished study, Louisiana State University, 1964), p. 54.

[2]A study by Rasch and Morehouse (see page 17) found that this did actually occur.

[3]Philip J. Rasch and W. R. Pierson, "Isotonic Training and Isometric Strength," Perceptual Motor Skills, XVI (1963), 229-230.

would indicate that the popular procedure of requiring three sets of six to ten repetitions in weight training might be suspected.

IV. CONCLUSIONS

Within the limitations of this study, the following conclusions were made:

1. Isometric training at a 95° angle of knee extension proved superior to isometric training at 125° and 155° of knee extension in achieving isometric strength gains at the 95° angle. However, isometric exercise at any of the three angles proved equally effective in bringing about isometric strength gains at 125° and 155°. All training programs were in conjunction with a physical education activity class.

   The above conclusion leads to the following statement: Position specificity of isometric strength gains was exhibited only at the 95° angle of knee extension indicating that exercise should be undertaken at that point in the range of motion if strength must be exerted at that angle. To develop strength at the 125° or 155° angle of knee extension, isometric exercise may be utilized at either the 95°, 125°, or 155° angle or isotonically in the 90° through 180° range of motion in knee extension.

2. Isotonic training in a 90° through 180° range of motion

of knee extension was significantly superior to the three isometric training positions at 95°, 125°, and 155° combined in developing isotonic knee extensor strength through the same range of motion. However, all of the three isometric training techniques did improve isotonic knee extensor strength in the 90° through 180° range of motion. All training programs were in conjunction with a physical education activity class.

3. Vertical jumping ability was significantly improved by the three isometric training techniques at 95°, 125°, and 155° angles of knee extension and the isotonic training in the 90° through 180° range of motion of knee extension. However, not one of the training techniques proved superior to any other technique in developing vertical jumping ability. All training programs were in conjunction with a physical education activity class.

V. RECOMMENDATIONS FOR FURTHER STUDY

1. A series of similar studies yielding findings on the major muscle groups of the human body.
2. A study comparing isometric strength at a specific point in a range of motion to isotonic strength through a 20° range of motion; 10° on each side of the isometric strength test point.

3. A study to compare the effects of a progressive increase of isometric strength training positions in a range of motion upon isometric strength at one position in the same range of motion and isotonic strength through a range of motion starting and ending at the extreme isometric training positions.

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APPENDIXES

APPENDIX A

INITIAL AND FINAL 95° ANGLE ISOMETRIC TEST SCORES OF THE FIVE TRAINING GROUPS

	Group I 95° Isometric		Group II 125° Isometric		Group III 155° Isometric		Group IV Isotonic		Group V Control	
Subject	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test
1	60	100	110	105	90	80	120	105	85	80
2	110	125	90	105	125	125	70	65	90	100
3	85	100	160	155	130	125	115	100	160	120
4	110	105	155	155	75	80	30	50	125	115
5	125	130	80	100	80	70	90	90	90	60
6	100	100	100	90	100	110	50	60	140	95
7	85	85	130	130	85	80	70	70	95	70
8	140	140	130	150	80	75	75	75	145	140
9	85	100	70	60	120	90	90	90	65	45
10	145	140	145	150	95	80	105	115	110	90
11	85	125	105	90	115	115	65	75	100	80
12	95	105	105	120	125	95	145	125	110	110
13	100	100	110	85	110	100	80	80	110	100
14	55	55	80	65	140	130	65	75	95	95
15	130	125	70	55	90	60	120	150	90	65
16	160	175	70	90	130	110	120	100	100	90
17	75	90	100	120	125	130	55	60	55	80
18	100	110	120	115	90	110	110	140	100	100
19	105	120	80	90	110	110	130	140	120	115
20	100	130	55	65	110	125	135	160	70	60
21	170	180	125	120	90	80	85	110	130	140
22	120	115	65	70	70	90	95	110	145	150
23	105	130	110	120	120	130	115	130	70	70
24	100	75	150	140	120	120	125	135	125	140

All scores recorded to the nearest 5 pounds

APPENDIX B

INITIAL AND FINAL 125° ANGLE ISOMETRIC TEST SCORES OF THE FIVE TRAINING GROUPS

	Group I 95° Isometric		Group II 125° Isometric		Group III 155° Isometric		Group IV Isotonic		Group V Control	
Subject	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test
1	390	350	300	385	160	390	310	490	215	400
2	240	390	220	405	375	585	210	300	290	440
3	325	480	365	540	245	435	350	450	260	430
4	430	560	415	600	225	430	140	310	270	585
5	295	500	350	530	320	560	420	550	275	310
6	220	500	390	490	385	410	150	370	280	280
7	260	265	360	550	335	400	245	355	310	375
8	410	570	410	475	295	500	195	450	470	485
9	300	500	270	485	295	460	295	400	190	265
10	205	320	380	490	335	420	410	490	290	425
11	410	400	305	465	190	400	350	580	210	325
12	380	280	390	455	390	220	350	540	380	240
13	425	535	370	330	280	280	260	250	405	325
14	200	330	235	480	390	610	240	250	360	310
15	410	415	320	360	390	495	340	410	205	230
16	310	460	280	345	440	580	350	410	290	340
17	335	295	310	570	450	405	160	250	150	130
18	295	270	395	505	450	470	280	280	425	300
19	450	490	400	420	335	380	380	540	280	320
20	390	425	270	300	255	335	300	550	305	255
21	410	540	350	460	360	515	265	330	425	565
22	390	340	410	580	250	400	280	320	470	520
23	180	390	440	580	305	310	230	350	240	255
24	225	370	330	485	290	420	250	320	400	375

All scores recorded to the nearest 5 pounds

APPENDIX C

INITIAL AND FINAL 155° ANGLE ISOMETRIC TEST SCORES OF THE FIVE TRAINING GROUPS

	Group I 95° Isometric		Group II 125° Isometric		Group III 155° Isometric		Group IV Isotonic		Group V Control	
Subject	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test
1	640	925	870	1250	695	730	810	985	750	680
2	510	985	775	885	775	1150	855	880	650	1065
3	580	1140	715	1135	740	805	825	860	890	1610
4	975	990	615	1350	740	785	350	765	950	1435
5	700	1155	950	1035	840	1225	810	985	555	1035
6	715	975	710	780	880	1005	750	1090	920	1040
7	815	955	805	1700	835	1170	780	860	1070	1320
8	1010	1215	805	1390	700	1030	805	850	920	1215
9	810	955	600	775	960	1120	710	965	670	590
10	1140	1030	970	1155	970	975	755	905	990	920
11	615	1205	835	1045	945	990	860	960	1060	1135
12	745	1200	635	1220	820	1150	1010	1650	920	915
13	840	1190	825	740	1230	1605	530	750	940	1025
14	890	640	900	1150	745	1435	930	1330	700	915
15	425	805	280	835	590	750	725	1265	615	820
16	830	1100	630	655	600	890	900	915	600	800
17	430	690	950	1220	1010	1400	865	1050	765	795
18	580	840	790	945	695	1115	700	1305	915	1265
19	970	925	1050	1010	700	1195	680	1090	875	1000
20	845	825	570	800	1055	1125	1325	1830	690	780
21	1180	1315	870	945	720	965	650	830	990	1210
22	810	1050	820	960	680	900	645	905	1095	1475
23	885	1265	830	1085	905	1225	965	980	750	895
24	580	775	860	1390	875	1450	925	1090	740	840

All scores recorded to the nearest 5 pounds

APPENDIX D

INITIAL AND FINAL ISOTONIC TEST SCORES OF THE FIVE TRAINING GROUPS

	Group I 95° Isometric		Group II 125° Isometric		Group III 155° Isometric		Group IV Isotonic		Group V Control	
Subject	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test
1	137	177	167	177	157	177	147	217	147	177
2	207	227	137	157	207	217	137	177	147	177
3	217	187	187	227	207	217	177	197	207	207
4	177	207	217	267	137	177	77	147	157	227
5	177	217	167	207	147	177	207	237	127	137
6	187	207	167	187	167	187	137	177	147	167
7	137	187	227	267	137	147	117	187	137	147
8	187	227	197	227	137	167	137	197	207	207
9	167	187	127	137	177	197	167	197	127	147
10	197	207	237	317	137	157	177	207	157	157
11	147	177	187	177	177	177	167	227	157	207
12	157	157	187	197	167	197	227	317	167	187
13	167	217	177	187	197	207	157	207	157	167
14	97	137	107	157	237	277	157	167	197	177
15	167	207	127	167	127	127	187	257	117	147
16	187	227	117	187	157	197	187	287	177	177
17	117	127	157	187	227	257	177	207	107	157
18	147	157	177	227	127	177	167	227	127	137
19	187	207	87	157	167	207	197	297	197	217
20	157	187	137	157	207	227	217	247	157	157
21	207	237	177	207	157	157	127	227	217	217
22	167	207	157	167	157	177	127	207	207	237
23	147	187	237	257	167	177	187	217	117	127
24	147	147	187	217	147	187	167	247	147	157

All scores recorded to the nearest 10 pounds

APPENDIX E

INITIAL AND FINAL VERTICAL JUMP TEST SCORES OF THE FIVE TRAINING GROUPS

	Group I 95° Isometric		Group II 125° Isometric		Group III 155° Isometric		Group IV Isotonic		Group V Control	
Subject	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test	Initial Test	Final Test
1	18.25	19.00	15.50	18.25	18.00	16.75	18.50	17.75	17.50	18.25
2	16.50	15.75	15.25	15.50	18.25	17.25	21.00	20.75	20.75	20.75
3	18.00	17.50	21.50	20.25	18.25	18.75	15.25	17.00	18.00	17.00
4	22.00	22.75	20.00	22.25	17.00	18.00	17.50	17.50	18.75	19.25
5	24.25	24.50	16.00	16.50	15.25	16.75	18.25	18.00	18.25	18.00
6	18.25	18.50	18.50	18.50	15.00	16.50	15.00	16.00	19.50	19.25
7	18.00	19.25	21.50	24.75	16.50	16.75	18.00	19.00	20.25	17.00
8	16.50	17.00	19.75	18.50	16.75	17.75	16.50	16.00	16.75	19.50
9	17.50	17.75	16.75	18.25	18.25	18.50	16.50	18.50	15.75	15.25
10	18.00	20.50	22.25	22.00	15.75	15.75	18.25	19.00	16.25	17.75
11	18.25	20.25	18.25	19.00	15.50	19.75	15.50	16.50	17.75	19.50
12	17.00	18.00	17.25	18.25	19.50	19.25	23.00	23.50	17.00	19.25
13	19.50	20.50	18.00	19.00	18.00	19.50	15.00	15.00	19.75	20.00
14	16.00	16.25	16.50	18.25	19.00	19.25	18.75	19.00	20.25	20.75
15	19.25	20.00	13.00	12.25	18.00	17.00	21.75	21.75	20.00	19.50
16	14.00	14.50	14.00	16.00	19.00	20.25	17.25	18.25	15.50	16.25
17	14.75	16.50	19.25	20.50	17.75	16.50	16.75	18.75	11.00	11.00
18	17.50	16.25	18.50	18.25	17.25	17.00	17.75	15.50	17.50	18.75
19	19.50	19.25	17.00	16.50	17.50	19.00	17.25	17.00	19.75	20.50
20	16.50	17.75	14.00	15.25	17.50	18.25	16.50	16.00	18.50	18.00
21	18.00	20.00	15.00	18.00	18.00	19.00	19.75	20.25	19.75	20.75
22	18.75	18.75	18.75	20.50	19.75	20.50	16.25	17.00	20.50	20.25
23	18.25	18.00	16.00	16.25	16.50	17.75	20.00	21.00	19.00	18.00
24	15.00	13.75	19.00	20.25	20.25	19.50	18.50	19.75	19.25	19.75

All scores recorded to the nearest $\frac{1}{4}$ inch

APPENDIX F

DATA COLLECTION CARD

NAME _____ AGE_____ HEIGHT_____ WEIGHT _____

COLLEGE STANDING (Fr.,Sr.,etc.) _____ MAJOR _____ MINOR _____

ACTIVITY _____ EXERCISE GROUP _____

	Initial Test Score	Retest Score	Final Test Score
ISOM 95°	_____	_____	_____
ISOM 125°	_____	_____	_____
ISOM 155°	_____	_____	_____
ISOT	_____	_____	_____
VJ	_____	_____	_____

VITA

The author was born in Tipton, Missouri on January 18, 1938. He was graduated from California High School, California, Missouri in 1955. The period from November, 1957 to August, 1960 was spent in the U.S. Army.

His Bachelor of Science degree was acquired from Southwest Missouri State College, Springfield, Missouri in May, 1962. The Master of Science degree was awarded in the spring of 1964 by Louisiana State University, Baton Rouge, Louisiana.

The author was employed by Appleton City High School, Appleton City, Missouri from September, 1962 until June, 1963. From September, 1963 until August, 1965 he served as a Graduate Teaching Assistant and a Graduate Research Assistant at Louisiana State University. Since that time he has been employed by Central Missouri State College, Warrensburg, Missouri as Assistant Professor of Physical Education.

He is married to the former Patricia Jo Allison, and they presently have one child, Allison Lee.

EXAMINATION AND THESIS REPORT

Candidate: Duane Ray Sterling

Major Field: Physical Education

Title of Thesis: Isometric Strength Position Specificity Resulting From Isometric and Isotonic Training as a Determinant in Performance

Approved:

Francis A. Drury
Major Professor and Chairman

R D Anderson
Dean of the Graduate School

EXAMINING COMMITTEE:

Jack K Nelson

Helen E Faust

Ralph E Steben

Date of Examination:

April 30, 1969